Training Primary Care Practitioners in Endodontics of Moderate Complexity Feasibility and Pilot Data on Skills Enhancement and Treatment Outcomes

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Training Primary Care Practitioners in Endodontics of Moderate Complexity: Feasibility and Pilot Data on Skills Enhancement and Treatment Outcomes

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Abstract

Background: With rising emphasis on pathways of patient care in dentistry, a pilot initiative involving collaboration by the London Deanery and London National Health Service (NHS) Commissioners provided training for general dental practitioners to upskill to the level of a 'Dentist with Enhanced Skills' (DES), in order to expand the availability of intermediate endodontic care to patients and improve the quality of endodontics in primary dental care. This provided the opportunity to test the feasibility of assessing the outcome of additional training in terms of treatment outcome in primary care dental services.

Aims: To explore the impact of dedicated training and experience on the quality of endodontic care provided by general dental practitioners (GDPs) working in primary care settings, using clinical, radiographic and patient related outcomes, as well as ascertaining patient and practitioner views, with estimated financial costs of the training.

Methods: This research involved a mixed methods approach with five components:

1: Pre-Post-test design of quality was used, with assessments of participants' (GDPs) technical ability: pre-, during- and post-intervention. The quality of endodontic treatment performed at the beginning and end of training, on endodontic training blocks (*in vitro*) and clinical cases (*in vivo*) from self-reported logbooks containing clinical notes and radiographs were assessed. A measurement tool for Process (clinical treatment process, quality of root canal filling as seen radiographically) and Outcome (healing as seen clinically and radiographically) was developed and tested. Inter- and intra-examiner reliability was calculated for all domains scored using radiographs. Statistical analysis involved McNemar, Z- and Mann-Whitney U tests to calculate the statistical significance for the change from Year 0 to Year 2.

2: Quality of endodontic care post-training, by these DES was measured using the same measures of process and outcome including post-treatment healing. Patient related outcomes

were measured using Oral Health Impact Profile - Endodontic Outcome Measure (OHIP-EOM). Descriptive analysis was carried out. A comparison was made between the Process scores at Year 2 of the training course and post-training.

3: Perspectives of participating patients were collected pre- and post-treatment using self-completed questionnaires and quantitatively analysed.

4: Perspectives of participating dentists were collected using anonymised self-completed written questionnaires and qualitatively analysed using framework analysis.

5: Cost of providing this service with training was estimated from available NHS data and compared to the cost of this treatment being provided in different settings such as a hospital (secondary care) or within primary care by a specialist endodontist.

Results:

1: Eight participants (dentists) completed the programme. Improvement in Process was seen for all domains *in vitro* ($p<0.05$), as well as *in vivo* for all domains of clinical treatment process ($p<0.05$) and improvement in achieving the correct working length of the root filling as seen by radiography ($p<0.05$).

2: DES recruited 135 patients requiring endodontics of intermediate complexity to the post-educational study. The quality of the process of providing endodontics was maintained following training ($p=0.081$ for clinical treatment process and $p=0.242$ for quality of root canal filling as seen by radiography). There were positive patient outcome [OHIP-EOM] scores after completion of treatment (mean score of 34.72, SD=10.74, n=120 pre-treatment and 25.85, SD=7.74, n=47 at follow-up).

3: The majority of patients reported they were satisfied, or very satisfied, with the service they received (72.5%, n=98); would use the service again (68.1%, n=92); and would recommend the service to friends and family (74.8%, n=101).

4: The DES perceptions of the training course were positive regarding the education and experience they received. They valued the supportive teaching and provision of educational materials; providing suggestions for development including more case discussions and teaching of more of the practical skills earlier in the course. Positive impacts were identified at individual (gains in knowledge, skills, confidence and personal development), patient (more teeth saved and quality of care) and system levels (access, value for money).

5: The total cost of this initiative was estimated at £664,400 including the purchase of necessary equipment (a training cost of £83,050 per dentist for both years). Within their NHS contract 1600 teeth were treated during the course (cost of treating each tooth during training approximates to £415.25 per tooth).

Conclusions: The findings of this study suggest that it is possible to carry out outcome based research in primary care, and that a training programme for General Dental Practitioners working within the National Health System (NHS) can be successful in changing practice and skills enhancement, with evidence of good clinical practice and patient related outcomes. The training and service provided were acceptable to practitioners and patients. Furthermore, process and outcome measures have been developed and tested for use in future training as well as for use as a stand-alone measurement tool for outcome of root canal treatment in any clinical setting.

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Abbreviation

CBCT	Cone-Beam Computed Tomography
CCG	Clinical Commissioning Group
CDS	Community Dental Services
COPDEND	Committee of Postgraduate Dental Deans and Directors
CQC	Care Quality Commission
DH	Department of Health
DES	Dentist(s) with Enhanced Skills
DPB	Dental Practice Board
DwSI	Dentist(s) with Special Interest
ESE	European Society of Endodontology
FDGP	Faculty of General Dental Practitioners
GP	General Practitioner (Medical)
GDC	General Dental Council
GDP	General Dental Practitioner
GDS	General Dental Services
HEE	Health Education England

JPEG	Joint Photographic Experts Group
MRC	Medical Research Council
NHS	National Health Service
NICE	National Institute for Health and Care Excellence
NTN	National Training Number
OHIP-EOM	Oral Health Impact Profile-Endodontic Outcome Measure
PCT	Primary Care Trust
PDS	Personalised Dental Services
PHE	Public Health England
SHA	Strategic Health Authority
UDA	Unit of Dental Activity
UK	United Kingdom
WHO	World Health Organisation
WTE	Working Time Equivalent

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Chapter 1: Introduction

Providing affordable quality healthcare has become a global challenge. According to the World Health Organisation (WHO, 2010), current global healthcare providers are said to be insufficient to meet the needs of the population, especially with rising patient expectations and demand. Numerous global documentation/frameworks applying to countries of all socioeconomic groups exist to redress this imbalance with particular emphasis on scaling up of the workforce with the education and training for health care workers as well as the development of meaningful instruments to assess outcomes (Capacity Project at www.capacityproject.org/framework/; World Health Organisation/Global Health Alliance, 2008, 2014; World Health Organisation, 2016a, 2016b). In the United Kingdom (UK), following an investigation into NHS Dental provision (House of Commons Health Committee, 2008a), the Steele Report (2009) introduced the care pathway for patients, recommending training and development of the current workforce in order to use the workforce imaginatively to ensure cost-effective, high quality dental services.

In accordance with above guidelines, this study is a pragmatic health services research project exploring the possibility of assessing postgraduate education and training in endodontics (a subspecialty of dentistry which provides root canal treatment) in terms of knowledge and technical skill but also in terms of outcomes of the treatment provided (clinical healing, radiographic healing and patient related outcomes).

1.1 Definitions

1.1.1 Endodontology

Endodontology has been described by the European Society of Endodontology (ESE) in 2006 as being ‘concerned with the study of the form, function and health of, injuries to and diseases of the dental pulp and periradicular region, their prevention and treatment; the principal disease being periodontitis, caused by infection’. The ESE guidance describes endodontic procedures to encompass ‘procedures that are designed to maintain the health of all or part of the dental pulp’ and when the pulp is diseased, injured or infected, treatment aims at ‘preserving normal periradicular tissues’ or ‘restoring the periradicular tissues to health’ (European Society of Endodontology, 2006). Technical skills required in endodontics therefore span a variety of areas from taking clinically acceptable radiographs and simple restoration of teeth to finding, cleaning and filling complex canal systems within a tooth (root fillings). Each of these aspects can vary in level of complexity from tooth to tooth and from patient to patient. An increase in knowledge may lead to the adaptation of different techniques that potentially improve technical skills.

1.1.2 Endodontic Treatment

In this study, the term ‘endodontic treatment’ was used for the provision of a completed root canal treatment for a tooth, which involves the removal of necrotic pulpal tissue or a previous root canal obturation material, disinfection and preparation of the root canal system followed by the obturation (filling) of the root canal system with an appropriate material. This is a sub-definition of that in section 1.1.1. The tooth should then be restored with a definitive restoration (or a temporary restoration and the patient referred back to their general dental practitioner for the provision of a definitive restoration). It was not expected that the dentists enrolled in this course would provide the definitive restoration following root canal treatment under the referral systems established for this pilot scheme.

1.1.3 Endodontic Treatment of Moderate Complexity

For the purposes of this study, the quality of care provided will be limited to patients with teeth requiring root canal treatment as defined by cleaning and filling of canal systems within teeth described as a difficulty level of 'moderate complexity' (Al-Haboubi *et al.*, 2014). Moderate complexity takes into account clinician factors, patient factors and tooth factors.

1.2 The Need for a Novel Training Initiative

Routine dental care is generally provided in 'Primary Care' (within General Dental Practices in the community) with a small proportion of complex care provided in 'Secondary Care' (NHS hospital) with the intention of shifting more of these services to Primary Care (Centre for Workforce Intelligence, 2014). General Dental Practitioners (GDPs) have a 'gate keeping' role within the NHS, referring appropriate cases to secondary care as necessary. In Primary Care, NHS statistics had revealed that in the year 2002-2003, in England & Wales, there were 63,519 endodontic treatments carried out in children or young people, at a cost of £3,516,889, accounting for 1.4% of the children's budget, and 1,040,565 endodontic treatments were carried out amongst adults at a cost of £50,204,951, amounting to 4.8% of the budget for adults (Dental Practice Board, 2003; Department of Health/Faculty of General Dental Practice (UK), 2006a). In the financial year 2001-2002, in London, 7.9% of the 2,875,750 claims for adults involved root fillings and that for children was 4.9% of the 649,154 claims (Dental Practice Board, 2001/2). Data reveal that the number of claims for remuneration including root canal treatment was 963,736 (1,086,620 teeth) for 2002/3 and that for 2003/4 was 942,940 (1,061,563 teeth) as reported in the Dental Review of the General and Personal Dental Services of the NHS (Dental Practice Board, 2002/3; 2003/4). Similar cost breakdown for more recent years is unavailable.

Following the introduction of the new dental contract for primary care in 2006, established to reduce costs and control the NHS dental budget, the House of Commons Health Committee report (2007/8) on Dental Services reported a 45% decrease in the number of root canal treatments provided since 2004, and an increase in the number of extractions provided (Health and Social Care Information Centre, 2007; House of Commons Health Committee, 2008b; McDonald *et al.*, 2010). There were reported changes in referral patterns and an increase in the number of cases being referred to secondary care (Izadi *et al.,* 2010; Ghotane *et al.,* 2015), possibly due to changes in remuneration for time-consuming treatment (McDonald *et al.,* 2010).

For the period 2014-2015, the number of claims for remuneration for “Courses of Treatment” including root canal treatment was 566,900 and the number of claims for specific clinical treatment items relating to endodontics was 611,500 (Health and Social Care Information Centre, 2014/15a). The figures for endodontic treatments and dental extractions in adults within a course of dental treatment as ascertained from ‘FP17 forms’ completed by primary care dental practitioners for remuneration are shown in Figure 1 (Dental Practice Board 2002/3; 2003/4; Health and Social Care Information Centre, 2009/10a; 2010/11a; 2011/12a; 2012/13a; 2013/14a; 2014/15a;). Data for the period 2005 - 2008 are not available due to changes in payment and data collection. Similar analyses have shown the same trend (Tickle *et al.*, 2011). There appears to be a significant reduction in the number of claims made that include endodontics, and a small overall increase in the number of claims containing dental extractions, however does not take into account any increase in referral to secondary care for dental extractions or endodontics.

The observed reduction in claims for the period 2009-2010 (Figure 1) for endodontic treatment may possibly be due to emphasis on active prevention or as a result of changes in undergraduate curricula and lack of suitable patients. It has also been suggested that fewer graduates are qualifying with confidence to manage technically challenging dentistry in such areas as oral surgery, endodontics and prosthodontics (Tickle *et al.*, 2011; Tanalp *et al.*, 2013; Davey *et al.*, 2015). The decline in the provision of complex restorative dental treatments has been linked to a decline in the quality of care within the NHS (House of Commons Health Committee, 2008b; Tickle *et al.*, 2011). There is an implication that there is an increase in the referrals to hospital for the provision of root canal treatment (Alani & Bishop, 2012).

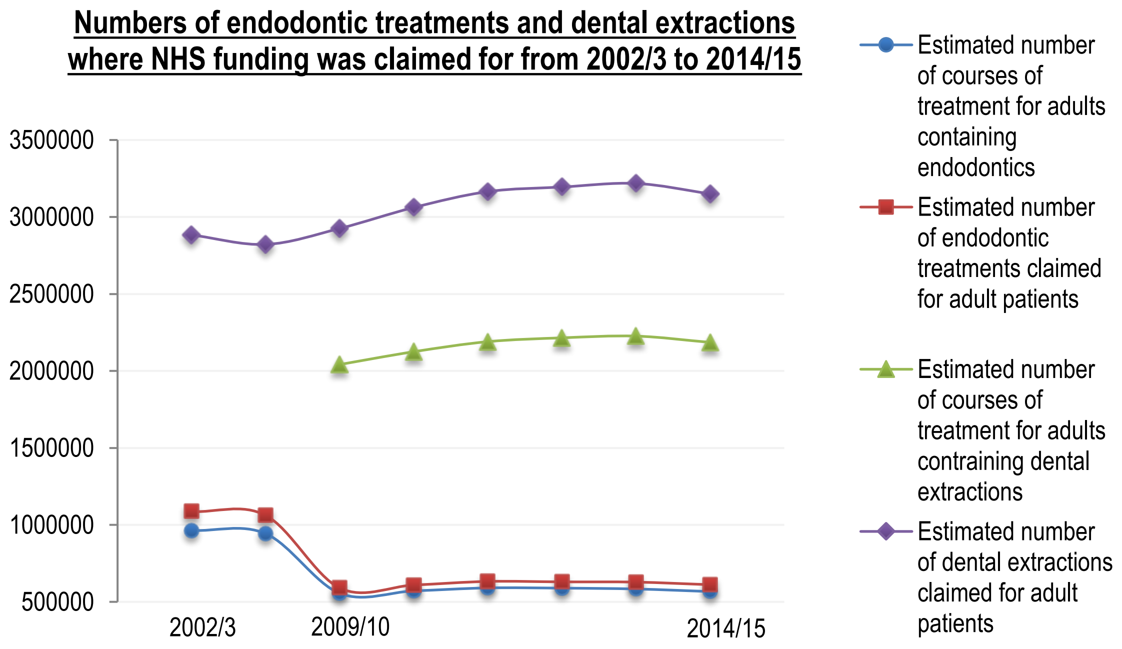

Figure 1: Dental Practice Board Dental Review of the General and Personal Dental Services of the NHS 2002/3, 2003/4 and Health and Social Care Information Centre NHS Dental Statistics data for the numbers of endodontic treatments and dental extractions claimed for within the NHS from 2002/3 to 2014/15 (actual numbers shown in Appendix A)

Health and Social Care Information Centre NHS Dental Statistics for England 2009/10a; 2010/11a; 2011/12a; 2012/13a; 2013/14a; 2014/15a; Dental Practice Board 2002/3; 2003/4

The introduction of the 18-week pathway for patients in secondary care, as described in the NHS operating framework for 2007-2008 (Department of Health, 2006), and the Referral to Treatment consultant-led waiting times: Rules Suite (Department of Health, 2015), have led to significant pressures within secondary care. Hospitals avoid developing and maintaining waiting lists for treatment in accordance with the 18-week pathway. In response, capacity has been optimised; however, this has been reported to be insufficient to meet the demand (Alani & Bishop, 2012). As a result, stringent criteria have been developed for the acceptance of patients for treatment within secondary care, limiting endodontic provision to high complexity cases, strategically important teeth and those patients requiring multidisciplinary care, some of which have been formally published as referral guidelines for restorative dentistry by a range of hospitals, all of which are associated with dental schools (Barts Health NHS Trust Website; Central Manchester University Hospitals NHS Foundation Trust Website; Royal Liverpool and Broadgreen University Hospitals NHS Trust, 2012; Kings College Hospital NHS Foundation Trust Website).

In secondary care, the Health and Social Care Information Centre Hospital Outpatient Activity data for different Treatment Specialties (2003/4; 2004/5; 2005/6; 2006/7; 2007/8; 2008/9b; 2009/10b; 2010/11b; 2011/12b; 2012/13b; 2013/14b; 2014/15b) show a steady increase in hospital 'attendances' for restorative dentistry since 2003 without a significant change in 2006/7 as shown in Figure 2 (http://digital.nhs.uk/). It is not possible to ascertain how much of this is related to endodontics, as these data have not been collected before (Hospital Episodes Statistics, 2007a; 2007b), or after (Hospital Episodes Statistics, 2015) the introduction of the new contract. It is equally difficult to ascertain whether this increase in attendances is being matched with increase in capacity within hospital dentistry. Commissioning guidelines (NHS Commissioning Board, 2013) are likely to limit the acceptance of treatment within secondary care and this is expected to affect endodontics.

The cumulative effect of the above factors could have resulted in a group of patients whose treatment needs do not qualify them for treatment within a hospital setting on merit of the treatment not being complicated enough or not in a strategic tooth. Yet these patients could also not ascertain the treatment with their own dentist as the dentist stated that they either never had or no longer had the confidence and skills to carry out the needed treatment. Hence, the development of the term dentistry of 'moderate complexity', the demand for which is not met in primary nor secondary NHS dental care. In London, this resulted in patients complaining to the then Primary Care Trusts and secondary care practitioners complaining to the then Deaneries for the shortage in access to dentists with the appropriate skills to meet this demand. If there is a demand for dental treatment and there is evidence to suggest that this need is not met in either primary or secondary care, there is a need to develop a workforce able to provide what is described as 'Tier 2' or endodontics of 'moderate complexity' in primary care (Al-Haboubi *et al.*, 2014; NHS England, 2015a).

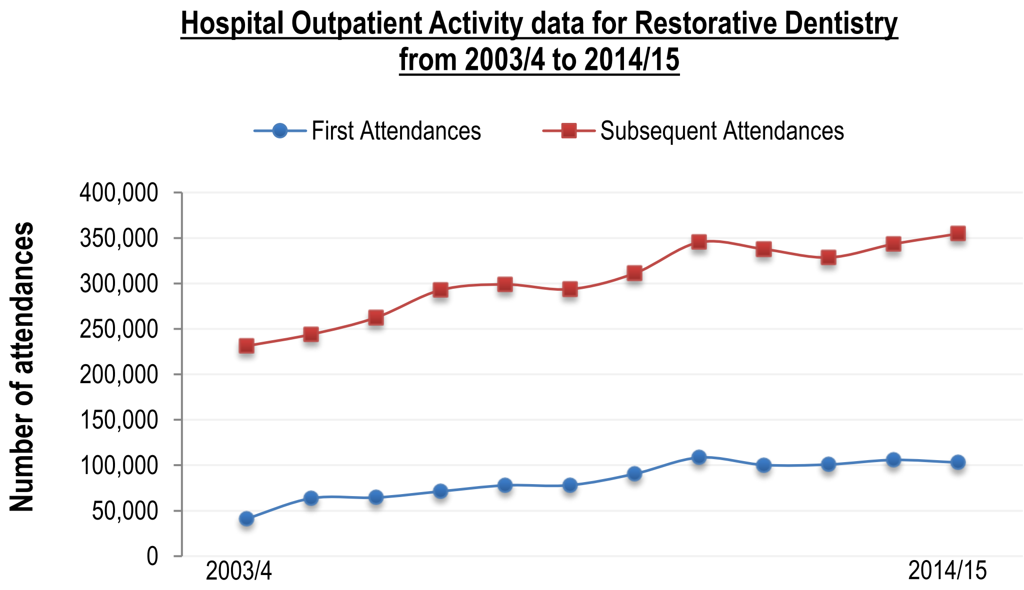

Figure 2: Hospital Episodes Statistics data for restorative dentistry form 2003/4 to 2014/15 (actual numbers shown in Appendix B)

NHS Digital website: http://digital.nhs.uk/

In order for more patients to have access to high quality endodontic treatment of moderate complexity within NHS primary care, a novel training pilot was developed (Al-Haboubi *et al.,* 2014). In 2009, the then London Deanery (now Health Education England) established this training course, in line with the Department of Health (DH) and Faculty of General Dental Practitioners (FGDP) national policy on Dentists with a Special Interest to address access to endodontic treatment in National Health Service (NHS) primary care with quality assurance (Department of Health/FGDP UK, 2004; Department of Health/FGDP UK, 2006a; Department of Health/FGDP UK, 2006b). This approach was in line with medical developments (Department of

Health/Royal College of General Practitioners, 2002; Department of Health, 2006b; Department of Health, 2007a; Department of Health, 2007b; Department of Health, 2007c; Darzi, 2008). It aimed to build expertise in the primary care setting and enable dentists who were generalists to develop enhanced skills in a distinct field whilst still continuing to work as a generalist for part of their time, following similar initiatives in medicine (Pawson *et al.,* 2016). The training was an innovative programme being run by what was then, The London Deanery, in collaboration with what were London Primary Care Trusts (PCTs) to provide endodontic patient care in dental practices during, and after, completion of the training programme, whilst also providing general dental care. More recently, following Steele (2009) and the Five-Year Forward View (Department of Health, 2014a), there is a move to take this concept forward across dentistry under the title 'Dentists with Enhanced Skills' or DES (Rooney, 2015).

1.3 The Training Initiative

Endodontics is a technically challenging branch in dentistry. Improving the technical skills of GDPs in this area is expected to improve the quality of endodontic treatment provided in the NHS and also to transfer skills to where they are needed (Department of Health, 2004; Department of Health, 2006a). In accordance with the current educational evidence-base, this multifaceted 'Dentists with Enhanced Skills (DES) in Endodontics' course, included the provision of educational reading material, interactive seminars, problem based learning, hands-on development of technical skills training using simulators and clinical experience, as well as reflective learning (Boyd & Fales, 1983; Mathers *et al.*, 1999; Paget, 2001; Neumann *et al.*, 2002, Cartney & Rouse, 2006, Dannefer & Henson, 2007; Weston *et al.,* 2008; Murad *et al.*, 2010). This course in endodontics was considered an attempt to change behaviour of general dental practitioners, in relation to the provision of endodontics as part of general dentistry. The timetable for the training course is shown in Appendix C.

The General Dental Council (GDC) regulates the dental profession (General Dental Council 2011, 2015) together with undergraduate education (5 years) and postgraduate specialist dental training (3-5 years). Health Education England (HEE) has responsibilities for higher specialist training whilst Universities and Trusts deliver specialist training. There are a variety of unregulated postgraduate educational/training courses (of varying duration) in which dentists can enrol, with the goal of improving their clinical skills and knowledge. Endodontics is considered a difficult 'craft' skill to master and there is evidence that many dentists either avoid the discipline because of clinical complexity, poor funding or medico-legal risks (Ghotane *et al.*, 2015, Al-Haboubi *et al.*, 2016). This DES in endodontics educational initiative allowed the training to take place around the clinical duties / responsibilities of the dentists concerned. The NHS patients treated during the programme were used to build skills and deeper learning with the aid of a reflective clinical practice logbook. The learning outcomes for this course were similar to those adopted by the Restorative Commissioning Guide in England as Level II competencies (NHS England, 2015a).

Participants for the above training programme were selected, via a combined nomination process by their PCT, and an interview panel consisting of members from the London Deanery, course teachers, and PCT representatives including a consultant in Dental Public Health. At the interview, records of cases treated in primary care were assessed. Twenty dentists were nominated by ten PCTs; nine of these dentists were selected via the interview process (from eight PCTs). NHS contractual arrangements were established to cover the additional endodontic treatment, to be provided by these dentists in their practices, on referral, either from with their practice or from outside practices. This treatment was remunerated at an enhanced fee within NHS primary care during and after training. The fee was increased after training. The provision of a definitive coronal seal was not included or remunerated within the treatment provided by the dentists providing the root canal treatment, and was expected to be provided by the referring dentist. Patients paid only once for the root canal treatment (likely to be Unit of Dental Activity [UDA] Band 2), and potentially paid to the referring dentist if this dentist commenced the root canal treatment prior to referral. If the tooth in question required a crown following root canal treatment the payment would be a UDA Band 3 payment, rather than a Band 2 payment, if completed within the same course of treatment.

Course ‘teaching days’ composed of seminar/didactic teaching sessions in the morning and practical hands-on sessions in a skills-laboratory in the afternoon, once a month, for 24 months. Between teaching days, the eight potential DES continued to treat patients in general dental practice, with the agreement that approximately one hundred patients per delegate would receive endodontic treatment of moderate complexity (Al-Haboubi *et al.*, 2014) as part of the practical training to gain clinical experience. These cases were recorded in a detailed clinical practice logbook or portfolio, where the stages and processes of treatment were documented with comments of reflective learning. These logbooks were discussed with the teachers as part of seminars and formed the summative end of Year 1 and Year 2 course assessments. This method of dental education has been recommended for dentistry (Mattheos *et al.*, 2009) and practical training in general practice settings has been shown to increase clinical experience when compared to hospital settings (Smith *et al.*, 2010). Additional equipment, where needed, was provided for each general dental practice, but the availability of basic endodontic equipment was a prerequisite for nomination to take part in the course.

1.4 Rationale for the Current Study

The rationale for this study was four fold:

- Development and testing of quality assessment tools for the outcome of root canal treatment
- Assessment of the feasibility of measuring outcome of training in endodontics using quality measures for the outcome of root canal treatment provided by DES
- Opportunity to explore the views of participant patients and dentists who undertook training

- Dissemination of research into primary care settings

Training in dentistry is a complex intervention as it is multifaceted and the implementation of training in dentistry should be assessed in terms of the outcome (Clark *et al.,* 2003). The three-circle model for specifying learning outcomes in medicine has been adapted to dentistry, and three key areas have been identified with regard to what a dentist is able to do: clinical information gathering (full and relevant patient history, comprehensive patient examination, arranging and interpreting appropriate investigations), treatment planning (in combination with the patient and recognising when referral is appropriate), and treatment procedures (carrying out the specific treatment interventions required to restore/maintain the patient's oral health). In addition to this, a number of other domains have also been suggested for how the dentist approaches their practice: application of basic clinical sciences, clinical reasoning and judgement, communication, health promotion, attitudes, ethical stance and legal responsibilities as well as information handling. The last dimension was described as the dentists' professionalism, in relation to their role within the health system and their personal responsibility towards lifelong learning (Clark *et al.,* 2003). These domains have been included in the *First Five Years* (General Dental Council, 2008) for undergraduate education. However the assessment is an examination of knowledge and ability to perform a task rather than the outcome of the treatment provided.

Training and research in primary care are considered difficult (Burke & McCord, 1993; Hopkins & Eaton, 1996; Burke *et al.*, 2002; Crawford, 2005; Mjör et al. 2005; Mjör, 2007). However, such training and research are of paramount importance as most routine dental care is provided in Primary Care (Morris *et al.*, 2000; NHS England, 2015a). The need for such training for the existing care providers has been documented (Steele, 2009). The outcomes framework for undergraduate training describes training outcomes, however not in the context of outcomes of treatment informing the level of learning (General Dental Council, 2011; General Dental Council, 2015a). Emphasis has been placed on measuring quality of dentistry within primary care in order that improvements can be made (Campbell & Tickle, 2013a; Tickle & Campbell, 2013; Campbell & Tickle, 2013b).

Post-graduate dental education is also assessed using traditional tools such as examinations and work place based assessments, rather than the outcome of treatment provided by the postgraduate trainee as outlined in the curricula for Specialty Training in Restorative Dentistry, Paediatric Dentistry and Endodontics (Specialist Advisory Committee in Restorative Dentistry, 2009; Specialty Advisory Committee for Paediatric Dentistry, 2009; Specialist Advisory Committee in Restorative Dentistry, 2010). Rather than assessing knowledge and ability to perform a task, the outcome of the dentistry performed is now being assessed (Dahlström *et al.,* 2015; Koch, 2013). The assessment of outcome of treatment is reflective of the quality of dentistry performed and includes the quality of life and patient experience of care (Department of Health, 2015/16; Department of Health, 2014a; Department of Health, 2015b).

There is a concern that clinical outcomes produced in hospital settings (secondary care) may not necessarily reflect the clinical outcomes achieved in general practice (primary care), thus prompting the recommendation that research should be conducted in 'real world' settings (Burke & McCord, 1993; RajaRayan, 2000; Wilson *et al*., 2002; Crawford, 2005). There are a few studies assessing the outcome of training in terms of the outcome of root canal treatment of primary care general dental practitioners in Scandinavian countries, but not the UK (Koch, 2013; Dahlström *et al.*, 2015).

The above described London Initiative to train DES in endodontics over a two-year period, provided an opportunity to conduct a feasibility study and obtain pilot data for evaluating the change in skills following a particular model of training of general dental practitioners as well as assessing the quality and outcome of root canal treatment provided by these DES. This study encompassed an understanding of the theory of improving dental skills, and models the potential intervention of training. It explored four components: change in skills from the start of the course to the end of the course, the quality of the treatment provided by DES when trained, and the views of the dentists who participated in the course. Additionally it was important to examine the cost of the Course. It was expected that findings would play an important role in informing future educational research in primary care. The quality assessment instruments developed in this feasibility study lend themselves to be used as measures of quality within, and outside of the NHS. Whilst a wider evaluation looked at overall service structure (Al-Haboubi *et al.*, 2014; Ghotane *et al.,* 2015; Al-Haboubi *et al.*, 2016); this research focussed on the educational initiative and the quality outcomes of treatment.

1.5 Overview of the Thesis

Chapter two of this thesis contains a review of the literature. Chapter three outlines the aims and objectives for this programme of research with the overall plan shown in Figure 3. Chapter four describes the methodology. Chapter five to nine reports the results in five sections: analysis of change in skills during the course, the maintenance of skills following the course with measurement of clinical, radiographic and patient related outcomes, patient perception of the service, dentists' perception of the course and an estimation of the cost of such training. Chapter ten discussed the learning from this feasibility study and the applications of the pilot findings. Chapter eleven is conclusions and Chapter twelve outlines the recommendations for practice.

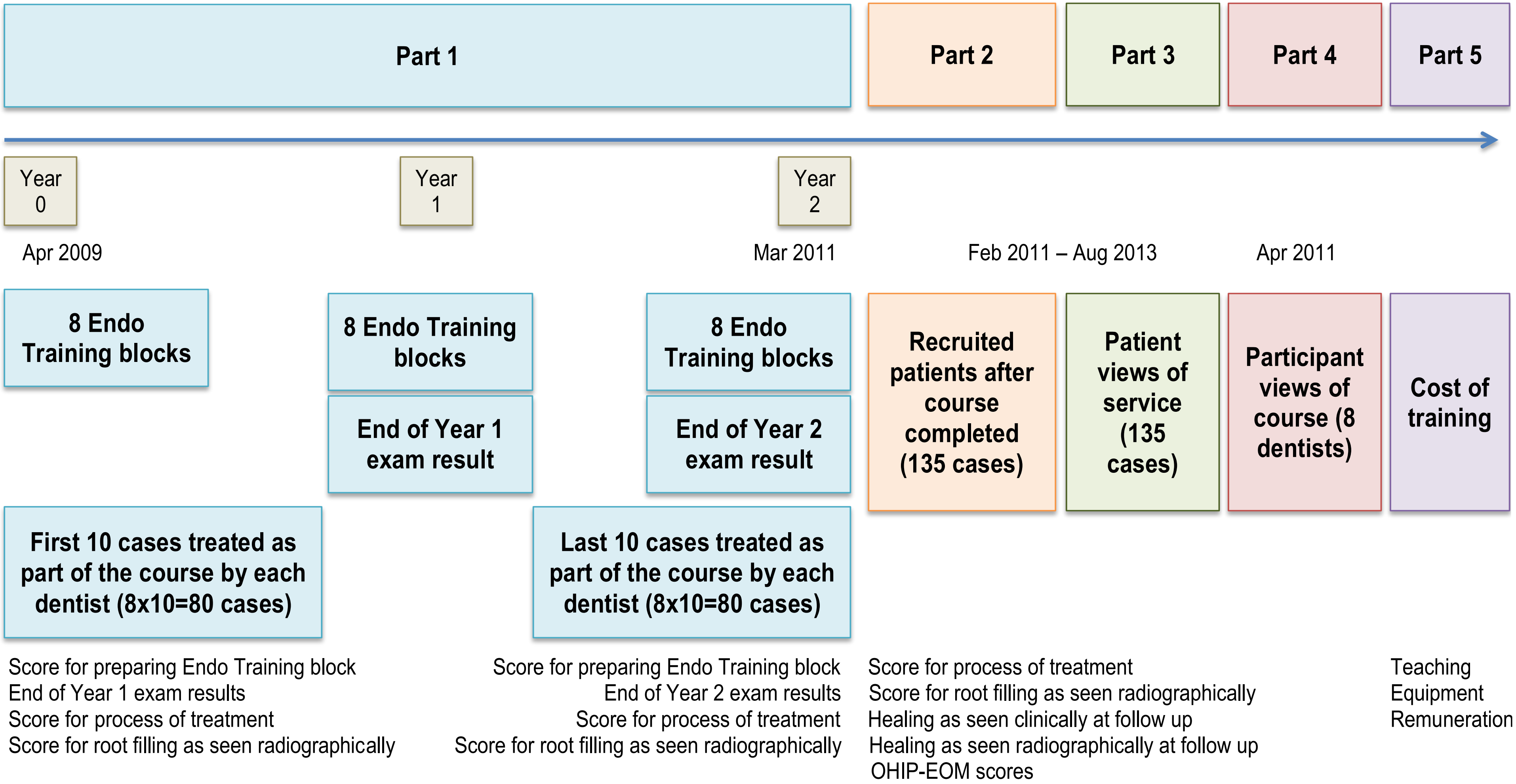

Figure 3: Overall plan for this feasibility and pilot study

Chapter 2: Literature Review

This chapter describes the literature pertaining to oral healthcare, healthcare research and endodontics. This includes the trends in oral health, need and demand for root canal treatment, the current workforce and education within dentistry, the National Health Service (NHS) arrangements for patients who require root canal treatment for one or more tooth as well as the changes in the political environment over the past ten years and the effects on as NHS provision of dental treatment. The current literature pertaining to pilot and feasibility studies, dental education, outcomes of root canal treatment and the available measurement tools, are presented. Searches relevant to each topic were carried out using MEDLINE and EMBASE. Professionally relevant documents were obtained from the General Dental Council Website. Policy documentation was obtained from official Department of Health of England, NHS England, HEE website publication sections, and the National Archive. Hand searches, Google and Google Scholar were also used to ensure broad searching.

A specific review of the literature concerning the design of primary care research in post-graduate education relating to root canal treatment is also described. This chapter informs the methodology, contextualises the findings and supports the discussion of this study. The limitations of most of the systematic reviews in dentistry are the lack of randomised controlled trials. Randomised controlled trials are few in dentistry possibly as a result of the difficulty of carrying out clinical research, the cost and ethical impact of randomisation. Due to the lack of high quality studies, longitudinal and cross sectional studies, especially those considered seminal have been included in this literature review.

2.1 Oral Health of the Population

Health is defined as ‘a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity’ (World Health Organisation, 1946). Its’ importance has remained through time although the emphasis has changed to continued improvement by prevention through holistic social intervention and not merely treatment of disease (World Health Organisation/Global Health Workforce Alliance, 2014). Health is considered a fundamental human right and has been the most important social goal worldwide (World Health Organisation, 1978).

In both global and national health care delivery, the drive is to provide a workforce that is able to meet the healthcare needs of the population (World Health Organisation/Global Health Workforce Alliance 2014; World Health organisation 2016a; World Health Organisation 2016b). In order to achieve this objective, it is important to understand the oral health status of the population and future needs (Bradshaw, 1994; Feldstein, 1999; Zurn *et al.,* 2004; Baltussen & Niessen, 2006; Segal *et al.,* 2008; Segal & Bolton, 2009; Segal & Leach, 2011). Universal access to healthcare, with a workforce to achieve the right person in the right place to provide the right care, is envisioned (Department of Health, 2014a; Centre for Workforce Intelligence, 2014).

Oral health has been defined as ‘a state of being free from chronic mouth and facial pain, oral and throat cancer, oral sores, birth defects such as cleft lip and palate, periodontal (gum) disease, tooth decay and tooth loss, and other diseases and disorders that affect the oral cavity’ (World Health Organisation, 2012). A distinction between improved oral health versus prevalence of oral diseases has to be made as the latter continues to be a public health issue in many countries with expanding elderly populations retaining their natural teeth for longer periods (FDI World Dental Federation, 2015). A compounding factor, especially in high-income countries, is people having received significant dental treatment maintaining these heavily restored teeth for longer (Office for National Statistics, 2012; United Nations Population Fund, 2012; NHS England Dental Analytical

Team, 2014; Centre for Workforce Intelligence, 2014). Even with the slow decline of dental caries in high-income countries, there is still likely to be a need for endodontic treatment due to the number of people with toothwear still on the rise (Gray *et al.*, 1970; Todd & Lader, 1991; Steele & O'sullivan, 2011; Steele *et al*., 2012). In a world of increased productivity and stress, the number of patients likely to require root canal treatment secondary to cracked tooth syndrome as a result of parafunctional activity is also likely to escalate (Opdam *et al.*, 2008). Traumatic injuries remain a significant cause of loss of vitality of teeth; in consequence, the need and desire for preservation of these teeth with root canal treatment is likely to remain (Borreani *et al*., 2010; Hellyer, 2011; DiAngelis *et al.*, 2012; Andersson, 2013; Zaleckiene *et al.*, 2014). The following section discusses the need and demand for root canal treatment in England and the UK.

2.2 Need and Demand for Root Canal Treatment

In the UK, within the NHS Primary Care, there is provision for root canal treatment. However, the extent of such demand cannot be accurately estimated for lack of published evidence. It is unknown if the NHS System meets the current demand, however it is ideal that the NHS meets demand, perhaps with a significant contribution from providers outside the NHS.

2.2.1 History of Root Canal Treatment

Endodontics is said to have begun in the 17th century (Cruse & Bellizzi, 1980a), with the most notable advance occurring when Pierre Fauchard (1678-1761) described the dental pulp putting to rest the idea of a 'tooth worm' causing caries and toothache (Castellucci, 2004; Lynch *et al.,* 2006). The first root canal instrument was developed in 1838; 'Gutta Percha' as a filling material for root canal treatments was introduced in 1847 (Castelucci, 2004). Rubber dam was introduced in 1864 (Curson, 1965) and the rubber dam clamp was introduced in 1873 (Anthony & Grossman, 1945). The first dental radiograph was taken in 1895 (Cruse & Bellizzi, 1980b). In 1908, the concept of establishing the correct length of the canal and avoiding overfilling canal was the (Coolidge 1960; Cruse & Bellizzi 1980b). By 1910, wide use of safe and effective use of local anaesthetic and dental radiograph machines occurred (Castellucci, 2004).

In the early part of the 20th Century, the theory of 'focal infection' in root canals, as well as their role in infective endocarditis, was developed resulting in numerous extractions of teeth, which was not proved otherwise until the 1940s and 1950s (Duke, 1918; Cooligde, 1960; Castellucci, 2004). Even then, root canal treatment was considered a difficult and a poorly remunerated task, although some dentists persevered in using aseptic techniques, with bacteriological and histological methods (Castellucci, 2004). This was soon followed by the use of radiographs to show that a 'pulpless' tooth can be saved (Castellucci, 2004). Since then, there have been significant advances including a better understanding of microbes, inflammation of the pulp, diagnostic testing, canal irrigation, equipment such as ultrasonic devices, electronic apex locators, rotary instrumentation, lasers for disinfection, and devices for filling canal systems (Shabahang, 2005). There have also been significant advances in radiology including the introduction of cone-beam computed tomography (CBCT) and the development of nanotechnology (Kishen *et al.*, 2016). Despite the technological advances made in endodontics, the success rates have remained the same (Ng *et al*., 2007). It is argued that this may be a result of more complex cases being undertaken, when previously these teeth would be extracted or because the biological concepts behind root canal treatment have remained the same but the focus has shifted from microbial culturing for example, to purely mechanical and technical achievement centered outcomes (Ng *et al.*, 2007).

2.2.2 The Need and Demand for Root Canal Treatment

The need for dental treatment can be extrapolated from the Adult Dental Health surveys (Gray *et al.,* 1970; Todd & Walker, 1980; Todd & Lader, 1991; Steele *et al*., 2009; Steele & O'sullivan, 2011; Health and Social Care Information Centre, 2011), which do not specifically look for the number of root filled teeth, as the survey involved only clinical examination. The most recent Adult Dental Health Survey (Steele *et al*., 2009; Steele & O'sullivan, 2011; Health and Social Care Information Centre, 2011) reported that the volume of edentate patients had fallen 22% since 1978, with only 6% being completely edentulous in 2009. Sixty-seven percent of adults had between 27 and 32 teeth and only 10% had excellent oral health. It is expected that 90% of those aged 35-44 in 2009 are likely to retain 21 teeth or more by the age of 80 years (Health and Social Care Information Centre, 2011; Steel *et al.,* 2012). Of the population of England, Wales and Northern Ireland, 94% were found to be dentate, having at least one remaining tooth (Health and Social Care Information Centre, 2011). It is clear from the Adult Dental Health Survey in 2009, that the population values the maintenance of pain-free teeth as difficulties of chewing and smiling as a result of pain and missing teeth were identified as impacting on their oral health (Health and Social Care Information Centre, 2011). If primary dental disease control is inadequate, and yet there is emphasis on maintaining teeth through the dental challenges posed by ageing, there is likely to be a need for root canal treatment and retreatment in the future (Boyle, 2011; Nadig *et al*., 2011). The exact number of people or teeth requiring root canal treatment at any one time, in each country, is unknown; however there are reports that 7% of dentate adults in England show one or more clinical sign(s) of endodontic infection (Qualtrough, 2014; Alani & Bishop, 2012). All of these teeth may not be appropriate for endodontic treatment, as some may be restorable or within a neglected mouth where primary disease control will be more important.

General dental services are remunerated based on activity; hence demand related data have been extrapolated using activity related data, which have been collected. The dentistry market is reportedly valued at £5.73 billion, with a 90% increase in the market value from 1999/2000 to 2009/10, with the NHS sector having grown from £1.82 billion to £3.32 billion in the same period. It was estimated that a 58% of the market price was spending on NHS dental treatment (the remainder being spending on private dental care) and the NHS dental contract in England was considered a barrier to entry and expansion in the dentistry market (Office of Fair Trading, 2012). The demand for endodontic treatment has traditionally been described as being high in England (Department of Health/Dental and Optical Services division/FGDPUK, 2009) as reflected by the number of root canal treatment performed as described in section 1.2 of this thesis.

2.2.3 Alternatives to Root Canal Treatment

The prospect of tooth loss is less dramatic these days as there are a variety of options for filling the space from lost teeth through to the provision of implant-retained prostheses. A number of recent articles have looked at the virtues of maintaining a natural tooth in relation to accepting a space or providing a prosthetic replacement (Cohn, 2005; Cohen & Hargreaves 2006; De Backer *et al.,* 2007; Doyle *et al*., 2007; Torabinejad *et al.,* 2007; John *et al.,* 2007; Zitzmann *et al*., 2009).

One of the simplest options is to accept the space left by the extraction of a tooth, as no further treatment is required. This is somewhat reversible, as the options for filling the space are still potentially available. When posterior teeth are lost, function has been said to be adequate as long as there are four opposing posterior units (one molar tooth being equivalent to two premolar units) and this has been termed a shortened dental arch (Kayser, 1981). Although, now dated, this is considered a seminal study, which assessed the oral function of 118 patients attending a dental school in Nijmegen (Netherlands), grouped into six classes according to the degree and distribution of contacting posterior units. Twenty four percent of subjects possessed a complete dentition and 82% of patients were functioning with a shortened dental arch for more than 5 years. The largest number of subjects was in the fully dentate group, with an even distribution in the other five groups. Oral function was measured using a ‘chewing test', where light-absorbing materials were released from raw carrots during chewing. The number of chewing strokes and patient complaints with oral function were recorded.

A shortened dental arch was not shown to lead to craniomandibular dysfunction or oral discomfort (Witter *et al*., 1990, Witter *et al*., 1994, Sarita *et al*., 2003a). However, with decreasing number of occluding units, the chewing strokes needed for swallowing increased (Kayser, 1981; Sarita *et al*., 2003b). The drifting of adjacent teeth and over eruption of opposing teeth leading to loss of inter-occlusal or restorative space is a possibility, the movement is largely clinically insignificant in periodontally health adult patients, and long-term stability is possible (Love & Adams, 1971; Witter *et al*., 1987; Kiliaridis *et al.,* 2000; Shugars *et al*., 2000; Witter *et al*., 2001; Craddock & Youngson, 2004; Christou & Kiliaridis, 2007). Although, not randomised controlled trials, these studies compare groups with shortened dental arches with control groups to measure clinically important parameters.

Accepting a space may not be preferred to saving a tooth of strategic importance (Zitzmann *et al*., 2010). Additionally, the loss of a tooth may lead to further alveolar bone loss (Van der Weijden *et al.,* 2009; Hansson & Halldin, 2012). In the upper jaw, a shortened dental arch was viewed negatively due to aesthetics therefore accepting a space is unlikely to be possible in the anterior zone (Kayser, 1981; Oosterhaven *et al.,* 1989). The psychological impact of having a space in the mouth has been recognised for quite some time with some reports of patients likening a space left by a missing tooth to 'trouble with relatives' (Haugejorden *et al*., 1993).

If maintaining a space is unacceptable, there are options for removable prostheses (dentures) and fixed prostheses (bridges or implants). The advantages of partial dentures include restoring of appearance, mastication and function, and the disadvantages include potential damage to hard and soft tissues (Davenport *et al*., 2000a; Petridis & Hempton 2001). Removable prostheses are a largely reversible method of restoring spaces, although there is potential for damage to abutment teeth if excellent oral health is not adhered to. This may not be ideal in patients with periodontal disease or recurrent carious lesions as poor oral hygiene and plaque trapping around the removable prosthesis may lead to the demise of the remaining dentition (Bergman *et al*., 1995; do Amaral *et al.*, 2010). Denture construction may take four to six visits to deliver and there are associated laboratory costs. Long-term maintenance is likely to include caries prevention and maintenance of periodontal stability as well as replacement of the prosthesis. Patients may encounter social issues with wearing a removable appliance and fail to internalise removable appliance therefore choosing not to wear removable appliances, especially if only posterior teeth are missing (Jepson *et al.,* 1995; Davenport *et al*., 2000b; Knezović Zlatarić *et al*., 2003; Clark *et al.*, 2004; Allen *et al.,* 2008). No significant differences have been found in patient related outcomes with provision of a removable denture and acceptance of a shortened dental arch in a pilot multi-centre randomised controlled trial in 14 dental schools in Germany including only thirty-four patients (Wolfart *et al*., 2005). While healing after extraction occurs, there is possible need for temporary wear of an immediate denture even if the definitive restoration is likely to be a bridge or implant retained prosthesis.

Conventional and adhesive fixed prostheses include cantilevered and fixed-fixed designs of bridges using natural teeth as abutments to restore spaces. Bridges are well tolerated by patients (Sonoyama *et al*., 2002; Szentpetery *et al*., 2005; Tan *et al.*, 2005; Geiballa *et al*., 2016). These studies utilised self-completed patient questionnaires prior to and after providing prostheses of conventional and resin retained designs, mainly in dental hospital settings. Sample sizes varied between 33 and 192 patients, and often far less than sample sizes indicated as in the study by Sonoyama *et al*., (2002). These were usually cross sectional studies and not randomised controlled trials. Some used an OHIP questionnaire (Sonoyama *et al*., 2002; Szentpetery *et al*., 2005) and some used other non-validated questionnaires (Tan *et al.*, 2005; Geiballa *et al*., 2016).

For conventional bridgework, there is a requirement for tooth preparation, potential for de-cementation of restorations, and the need for recycling of restorations (Brägger *et al.,* 2001). A cross sectional study of 77 teeth that were vital before bridge placement, showed the long-term damage to abutment teeth has been approximated at 30% losing vitality at 10 years and 35% at

15 years after placement of various fixed-fixed conventional bridge designs between 1981 and 1989 in a dental school in Hong Kong reviewed at 187 +/- 23 months (Cheung *et al*., 2005). It was not clear who carried out the clinical examination but the radiographic examination as carried out by two pre-calibrated independent examiners with inter-examiner Kappa scores of 0.79. Although, not ideal as there was reliance on accurate record keeping prior to treatment, some patients who failed to attend a review were questioned via telephone rather than clinically examined, the limitations of assessing pulp vitality clinically and radiographically while restored with bridges, there are no better studies, especially from the UK.

A minimum of two appointments is needed for construction the definitive prosthesis, with an interim temporary restoration. Again, laboratory costs with long-term maintenance and replacement costs need consideration. A meta-analysis of data from a systematic review of the literature (19 studies of prospective and retrospective designs, with clinical examination at least at 5-year follow-up) revealed conventional fixed-fixed bridges have a ten-year probability of survival of 89% and 10-year probability of success of 71% (Tan *et al.,* 2004). A meta-analysis of a systematic review of cantilevered bridges (13 studies with a minimum follow-up time of 5 years and with clinical examination at follow-up) had a reported survival of 82% and success rate of 63% at ten years, with the most common cause of complications being loss of pulp vitality of the abutment tooth (Pjetursson *et al.,* 2004). In these studies various bridge designs are combined, however details of each study are available within the systematic reviews.

For adhesive bridgework, in which the tooth preparation is minimal or not needed (Djemal *et al.,* 1999; King *et al.,* 2015), there is potential for de-cementation. However the reported median survival for cantilever designs is 9.8 years, for fixed-fixed designs is 7.8 years (Djemal *et al*., 1999). In no-preparation cantilever designs the abutment tooth is left unharmed even if the bridge fails. Djemal *et al.* (1999), in a cross sectional study, assessed 832 restorations in 593 patients in a post-graduate dental institute setting. The technique, operator, materials and bridge designs were not controlled for. Where patients did not attend follow-up, the patient or general dental practitioner looking after the patient was contacted to ascertain if the restoration was still in service. The restorations were assessed by three of the authors with no mention of calibration, training or inter/intra- examiner reliability. A third of restorations were placed in patients with missing teeth, who usually also have small potential abutment teeth. Despite the heterogeneity of the sample details for each design of bridge can be extracted from the publication. There is reported 65% survival at 10 years where all designs of resin-retained bridges were pooled in a systematic review of retrospective and prospective cohort studies with a minimal follow-up time of 5 years (Pjetursson *et al.,* 2008). Seventeen studies reporting sixteen different cohorts were included for meta-analysis, the oldest of which was carried out in 1991. The studies were heterogeneous, with a variety of bridge designs, operators, settings (mostly universities or specialist clinics) and materials being included. Many studies were excluded due to not meeting the minimum requirement of 5-year follow-up. Most recent publications still report on patients treated between 1994 and 2001, where the outcome of 771 resin-retained bridges performed at a dental school were reported to have 80% survival rate at 10 years (King *et al.,* 2015). Bridge design and materials were standardised, operators were various and the follow-up examinations were carried out by one of the authors without mention of training or intra-examiner reliability.

The alternative fixed option is implant-supported prostheses to restore spaces. There is a need for a surgical phase, with the need for grafting procedures if there is a lack of bone or appropriate soft tissue (D'Addona *et al.,* 2012) with good survival rates reported in a systematic review of the literature involving 39 studies including three randomised controlled trials (Del Fabbro *et al*., 2004). Complication rates and failure of implant have been reported as higher in smokers and those prone to periodontal disease, without professional maintenance (Tran *et al*., 2016) as well as those suffering from diabetes, those undergone head and neck radiation and postmenopausal oestrogen therapy (Moy *et al*., 2005). There may be difficulty with achieving ideal aesthetics in anterior region and potential risk of damage to other structures (roots of adjacent teeth, antrum, and inferior dental, lingual and mental nerves) such that implant therapy may not always be possible (Palmer *et al*., 1999). There is a need for long-term maintenance of implant-supported prostheses as biological and technical complications may occur (Goodacre *et al.*, 1999; Brägger et al., 2001; Goodacre *et al*., 2003; De la Rosa *et al.*, 2013; Atieh *et al.*, 2013; Bidra *et al.*, 2016; Tran *et al.,* 2016). The economic costs are higher than that of root canal treatment and removable prostheses, however comparable or lower than that for tooth supported conventional prostheses in the long term (Torabinejad *et al.*, 2007). The reported survival rate at ten years for implant supported fixed partial dentures is 87%, that for implant supported single crowns in 98% (Pjetursson *et al.,* 2007).

Root canal treatment and maintenance of the natural tooth has high success rates (Ng *et al.,* 2011a) and high survival rates (Lazarski *et al.,* 2001; Salehrabi & Rotstein, 2004; Chen *et al*., 2007; Torabinejad *et al*., 2007; Lumley *et al.,* 2008; Tickle *et al.,* 2008; Ng *et al.,* 2010; Ng *et al.,* 2011b). The advantages are the retention of the tooth where non-healing can still be managed and result in tooth retention with fewer interventions than with implant-supported prostheses (Doyle *et al.,* 2006). The natural tooth will maintain alveolar bone and soft tissue contours (Cawood & Howell, 1988; Schropp *et al*., 2003; Araujo & Lindhe, 2005). Root canal treatment can avoid extractions in medically compromised patients such as those who have undergone radiotherapy to the head and neck, those taking bisphosphonates, or who have blood dyscrasias where special precautions or avoiding extraction may be favoured (Renton *et al.*, 2013). However, root canal treatment is a lengthy and complex procedure, which is only possible when there is enough remaining tooth structure for restoration post root canal treatment (Bandlish *et al.,* 2006). A minimum number of radiographs are required (European Society of Endodontology, 2006) and can take more than one appointment to complete, depending on complexity. The cost implications to the dentist such as time and the cost of single use root canal instruments (Department of Health, 2007d) are often reflected in the price presented to the patient. The cost to the patient also includes the purchasing of a definitive restoration for the tooth post root canal treatment. Long-term review is usually minimal unless symptoms arise and patient related outcomes are similar with root canal treated teeth and implant supported single crowns (Gatten *et al.,* 2011).

A systematic review revealed weighted success and survival of implant supported single crowns; fixed-partial dentures (bridges) and root filled teeth as shown in Table 1 (Torabinejad *et al.,* 2007). Although, carried out in accordance with guidance for systematic reviews, the included studies were not randomised controlled trials, were heterogeneous, and limited to publications in English, this was a thorough summary of the available literature. The success rates of root filled teeth are comparable to the success of fixed-partial dentures at more than 6 years follow-up and the survival of root filled teeth is comparable to that of implant supported single crowns at more than 6 years follow-up (Torabinejad *et al.,* 2007). Other studies have also reported no significant difference in the survival rates of root filled teeth and of implant supported single crowns (Doyle *et al.,* 2006; Doyle *et al.,* 2007; Iqbal *et al.,* 2007; Hannahan & Eleazer, 2008; Morris *et al.,* 2009). Therefore conventional root canal treatment or retreatment is the clinical procedure of choice whenever a tooth is restorable and is involved in endodontic pathology. As Morris *et al.,* (2009) have indicated, one of the difficulties in making this comparison is that implants are measured often in terms of survival (implant is still present despite associated problems), whereas root filled teeth are measured in terms of success (the tooth is present with signs of clinical and radiographic healing). It is also noteworthy that specialists often provide implants and general dental practitioners most often provide root canal treatment (White *et al.,* 2006). Survival rates of implants provided by inexperienced practitioners have been reported as lower by approximately 20% compared to that provided by implant specialists (Morris & Ochi, 2000a; Morris & Ochi 2000b; Setzer & Kim, 2014). In comparison, root canal treatment provided by specialists also have a higher success rate that generalists (98.1% and 89.7% respectively) at five years post treatment (Alley *et al.,* 2004).

Table 1: Weighted success and survival rates of a systematic review comparing implant supported single crowns; fixed-partial dentures (bridges) and root filled teeth

Years of follow-up	**Implant supported single crown**		**Fixed-partial dentures (bridges)**		**Root filled teeth**	
	Success	Survival	Success	Survival	Success	Survival
2-4years	99%	96%	78%	94%	89%	94%
4-6years	98%	97%	76%	93%	94%	94%
6+ years	95%	97%	80%	82%	84%	97%

Torabinejad *et al.* 2007

When outcomes of alternatives to maintaining a natural tooth are considered, including the biological, financial, and psychological concerns of patients, it is better to spend available resources to maintain a natural tooth for as long as possible, in order to ensure that the commencement of the lifetime of the alternative to maintaining a space is delayed (Torabinejad *et al.,* 2007).

2.2.4 Benefits of Endodontic Treatment

For a patient with pain of endodontic origin, two options are available: root canal treatment or extraction of the tooth. The treatment option is dependent on both clinical evaluation and patient factors such as access to endodontic treatment and economic considerations. Patients can access root canal treatment from the primary care sector (NHS General Dental Services or private sector) or the secondary care sector (hospital services). Hospital services are limited by capacity and therefore have limiting acceptance criteria for treatment in a hospital environment. This includes cases of high complexity, medical compromise, developmental disorders, oncology and complex trauma. Potentially, this leaves a group of patients who require endodontic treatment but do not qualify for root canal treatment in a hospital environment and yet are unable to receive this treatment in NHS practice possibly as the treatment is considered to be out with the level of practice expected from a GDP (General Dental Council, 2011; General Dental

Council, 2015a). These patients may also be unable to afford the cost of root canal treatment in the private sector. It would be ideal for these patients to receive quality root canal treatment in a primary care setting, as it is likely to be more convenient and efficient for the patient as well as reducing the current strains on the hospital services. A third, less satisfactory treatment option, is to continue to live with the affected tooth, however there may be systemic implications associated with this approach. Provision of an endodontic service is important because of its contribution to health. If a number of patients are unable to access root canal treatment, with the resulting intervention being extraction, this may impact on the individual's quality of life (QoL) with possible wider effects on social and economic aspects of the community.

The effect of tooth loss in relation to QoL has been investigated in several studies (Gilbert *et al.,* 2004; Akifusa *et al.,* 2005; Mack *et al.,* 2005; Baba *et al.*, 2008; Brennan *et al.,* 2008; Niesten *et al.,* 2012) with a general consensus that tooth loss had a negative impact on quality of life, citing reduction in chewing ability following the loss of teeth as a cause.

A longitudinal study by Dugas *et al.* (2002) reported on the QoL and satisfaction outcomes of root canal treatment on two Canadian populations (n=83 and n=36) aged 25-40 years in two different dental schools. A QoL instrument was a structured questionnaire based interview, designed to measure the subjects' perception of functional, social and psychological impact of endodontic disease on their well-being and semantic differential scales that measure satisfaction related to different aspects of root canal treatment was used (17 questions chosen from OHIP 49, with a five-point Likert scale). One examiner, calibrated using radiographs with high intra-examiner reliability, assessed healing. The subjects acted as their own controls by reporting how the disease pre- and post- root canal treatment affected the quality of life. In this study population almost all of the subjects reported pain prior to root canal treatment but less than 50% reported a form of functional limitation. Physical disability was reported more often by those with an annual family income of over $30,000 than those with a lower income. Subjects who had experienced ‘painful aching’ prior to root canal treatment reported the highest rate of improvement and those who had difficulty with ‘pronouncing words’ reported the lowest rate of improvement. The logistic regression model for ‘predicting improvement in the ability to perform usual jobs’ in this study predicted that the subjects are five times more likely to perceive improvement if the subjects had a high school education. Subjects who had an anterior tooth root canal treated rather than extracted reported the peak satisfaction of 100% (Dugas *et al.*, 2002). Gatten (2011) compared QoL relating to patients with endodontically treated teeth with implant treatment. Both cohorts reported similar QoL and satisfaction; however, patients recommended preserving the natural dentition wherever possible (Gatten *et al.,* 2011).

The following section describes the current workforce to provide root canal treatment to maintain natural teeth and describes the need for educating this workforce to meet the needs of the population it serves (Department of Health, 2014a).

2.3 Delivery of Root Canal Treatment

Historically, provision of root canal treatment has been within the remit of the NHS dental contracts for General Dental Services and personal Dental Services (NHS England, 2005a; NHS England, 2005b), which came in to force on the 1st of January 2006 and applied to England only. The procedure is still taught at an undergraduate level and it is expected that new graduates are competent at completing a range of restorative dental procedures including provision of root canal treatments of single- and multi-rooted teeth as stated in the First Five Years (General Dental Council 2008). No further detail is given in this document regarding the complexity of cases that were expected to be treated by these dentists, which has been superseded by ‘Preparing for Practice: Dental Team Learning Outcomes for Registration’ (General Dental Council, 2011; General Dental Council, 2015a). The outcomes of training include the expectation that dentists should be able to assess, diagnose, determine the prognosis of and manage the health of the dental pulp and periradicular tissues, using appropriate non-surgical treatment to prevent pulpal and periradicular disease in 'uncomplicated deciduous and uncomplicated permanent teeth' (General Dental Council 2011; General Dental Council 2015a).

2.3.1 Current Dental Workforce

The current dental workforce in England is comprised of dental teams working in primary and secondary care, both within the NHS (state-funded) and the private sector. These teams at their minimum consist of dentists, dental nurses and dental receptionists, but may also include dental hygienists, dental therapists, dental hygienist-therapists, orthodontic therapists, dental technicians and clinical dental technicians, with significant emphasis distribution of skill-mix and the dentist being supported by a multi-professional team (Centre for Workforce Intelligence, 2014, Boyle 2011). The provision of root canal treatment is not within the scope of practice for anyone other than a dentist (General Dental Council 2011; General Dental Council, 2013; Centre for Workforce Intelligence, 2014). General dental practitioners are independent contractors that choose to provide NHS dental services and/or dental treatment via the private sector (Boyle 2011).

The General Dental Council (GDC) is the regulator for the dental profession in the UK. There were no formal qualifications for providers of dental treatment until 1859. Dentistry was unregulated until The Dental Act of 1878 and Sir John Tomes was the first name on the Dentists' Register. In 1921 the practice of dentistry was limited to those with a professional qualification to practise dentistry (Cope, 1957). Restorative dentistry was recognised as a specialty in 1973 and encompasses the dental specialties of endodontics, periodontics and prosthodontics (RD-UK website). The specialist lists have developed since 1994, when the Chief Dental Officer's Report on UK Dental Specialist Training was published, including a specialist list for endodontics (General Dental Council 2006). Specialist lists were first held by the GDC in 1998 following the Mouatt (1995) review (Faculty of General Dental Practice [UK], 2014).

Gaining entry to the specialist lists at the time involved a process of 'grand parenting'; however, now is a process of demonstrating required competencies through recognised training pathways or mediated entry (Faculty of General Dental Practice [UK], 2014). One of the main reasons for the creation of specialist lists was to protect patients by informing patients and referring practitioners of the competencies of a practitioner to carry our certain treatments (Faculty of General Dental Practice [UK], 2014).

The GDC Register is the access point for patients to identify qualifications of their dentist and specialists. In the most recent facts and figures released by the GDC (2015), there are 39,432 registered dentists in the UK (78% are registered in England), 0.7% registered on the specialist list for endodontics and 0.8% registered on the specialist list for restorative dentistry (General Dental Council Facts and Figures available at www.gdc-uk.org/newsandpublications/factsandfigures/pages/default.aspx). It is likely that some individuals are registered on both specialist lists for endodontics and restorative dentistry; therefore, the true numbers are likely to be lower. The numbers on the GDC register for the past nine years are shown in Table 2.

Table 2: Number of dentists and specialists registered with the GDC from 2007 to 2015

Year	Number of registered dentists in the UK	Number of registered dentists in England	Number of dentists on the Specialist List for Endodontics	Number of dentists on the Specialist List for Restorative Dentistry
2007	35,419		198	297
2008	36,281		192	292
2009	37,049		210	304
2010	38,397		221	306
2011	39,307		222	301
2012	39,894		243	306
2013	40,423		260	317
2014	41,038	31,603	267	317
2015	39,432	30,800	269	311

General Dental Council Facts and Figures at www.gdc-uk.org/newsandpublications/factsandfigures/pages/default.aspx

There has been approximately a 10% increase in the number of registered dentists in the UK over the past nine years from 35,419 to 39,432. The proportion of specialists in endodontics has increased by approximately 25% in the same time frame from 198 to 269. The number of restorative dentists registered with the GDC has increased by approximately 5% within the past nine years from 297 to 311. This has implications for patients accessing dental care that is more complex than routine endodontic treatment. These dentists could work within the NHS primary or secondary care, in academic institutions where they have primarily a teaching and research role rather than NHS service provision, and/or in private practice. There is no list for registration for dentists with additional experience in endodontics. The public is therefore unable to easily source information on additional skills of dentists.

The data shown in Table 2, do not equate to whole time equivalents (WTE) therefore, are not necessarily a reflection of the NHS workforce. Reports have suggested that there are 3,301 WTE dentists working in both primary and secondary care including dental public health in 2009, described as a 22% increase from 1997, equivalent to 0.36 dentists per 1,000 per resident population in 1997 compared to 0.43 per 1,000 in 2009 (Boyle, 2011). These figures were explained as an overestimate, as the numbers of patients registered with a dentist was 54% in 1997 compared to 49% in 2006 (Boyle, 2011). Since then the measures have changed to the numbers of patients seen by an NHS dentist over the previous 24 months: 28.1 million (55.8% of the population) in 2006 compared to 28.5 million (55.4% of the population) in 2010, with much variation in the access to NHS dental services across England (Boyle, 2011). It should be noted that prior to the introduction of the Dental Gold Guide in 2009 (COPDEND website for Dental Gold Guide), those that trained in restorative dentistry could elect to have their name listed on all three GDC specialist lists for the subspecialties of restorative dentistry (endodontics, periodontics and prosthodontics). Therefore these dentists may have a variable level of skill in endodontics.

It is likely that the number of specialists in endodontics, dentists with enhanced skills from this initiative and dentists with experience in endodontics currently providing root canal treatment under NHS contracts may have enhanced value contracts; and the latter (dentists with enhanced skills) may not necessarily be reflected in the current GDC specialist list data. Of those general dental practitioners not listed as an endodontist or restorative dentist, it is unknown how many are providing root canal treatment within NHS primary care.

2.3.2 The Workforce Gap

Endodontic treatment may have become difficult to access in the NHS primary care sector as a result of change in remuneration, although it is in the remit of NHS primary care (Stock, 1991; Tickle *et al.,* 2011). The time and instruments/materials involved in endodontic treatment can be significant and current remuneration may mean providing treatment at a cost to the dentist/dental practice especially as many of the instruments for endodontics are single use (Department of Health, 2007d). A favourable contract may improve the access to endodontic treatment in primary care (Tickle *et al.,* 2011).

Additional evidence supports the lack of skills and training to complete root canal treatment as being factors in whether root canal treatment is performed in primary care or not (Stock, 1991; Ghotane *et al.,* 2014; Al-haboubi *et al.,* 2016). Since dental graduates are considered ‘safe beginners’ (General Dental Council, 2015a) it is not expected that they will possess all the skills required to be competent at all dental treatment. There is also an opinion that dentists are starting to de-skill as a result of the dental undergraduate education and NHS arrangements for dental care provision (Holt, 2008; Marlow, 2012; Mosedale & Batchelor 2012; Doherty, 2013). The lack of suitable teeth and patients, an ever developing undergraduate curriculum with limited number of hours of practical teaching have been cited as barriers to providing adequate knowledge and skills (Qualtrough, 2014). A view that young graduates may be more risk averse as a result of increasing medico-legal claims in dentistry, therefore may avoid complex treatment such as root canal treatment is emerging, and, as a result, publications are appearing addressing the medico-legal aspects of root canal treatment (Europe Economics, 2014; Patel & D'Cruz, 2016). There is some evidence for young female graduates to be more risk averse than their male counterparts, a difference that decreased with age, with specialists being less risk averse than generalists of the same gender; however male general dentists were still less risk averse than female specialists (McGrath & Rossomando, 2015). It was also noted that the average risk score increased with population density (McGrath & Rossomando, 2015); hence the more practice gained, the less risk averse the dentists become. With growing increase in females within the dental workforce, the risk adverse behaviour is likely to continue (Gallegher *et al*., 2007; Schofield & Fletcher, 2007; McKay & Quiñonez, 2012; General Dental Council Facts and Figures at www.gdc-uk.org/newsandpublications/factsandfigures/pages/default.aspx). The consequences of a largely female workforce may mean more part time or flexible working patterns. However, the changes in generational priorities may mean that 'Generation X' men are also less likely to work long hours than 'Baby Boomers' leading to the number of GDC registered dentists potentially being a misrepresentation of the whole time equivalents available for provision of care (Schofield & Fletcher, 2007; Khatoon *et al*., 2013).

With upcoming commissioning guidelines for restorative dentistry for tiered levels of dental provision (NHS England, 2015a; 2015b; 2015c; 2015d), there will be a need for those with extended skills to be able to provide the treatments that are considered too difficult for general dental practitioners and not complicated enough for specialists. The concept of dentists with enhanced or extended skills was first mentioned a decade earlier with the introduction of Dentists with Special Interest following the medical model (Department of Health/Royal College of General Practitioners, 2002; Department of Health/FDGP UK 2004). The aim was to bring care closer to patients with faster and more efficient access to a wider range of services in primary care being the main driver; however included intentions were also to give patients choice, recognise skills developed by dentists, and preparation for the 2006 dental reform, with the overall impact believed to be better for patients, dentists and for the NHS (Department of Health/FGDP UK, 2004). Previously published Department of Health documentation does provide guidance for appointing dentists with enhanced skills for a number of dental disciplines including endodontics, special care dentistry, conscious sedation, orthodontics, periodontics, oral surgery and prison dentistry (Department of Health/FDGP UK 2006a; 2006b; 2006c; 2006d; 2006e; 2007; NHS Primary Care Contracting/FGDP UK, 2007; Department of Health/Dental and Optical Services Division/FGDP (UK), 2009). These guidelines describe the use of a portfolio and curriculum vitae of dentists to validate experienced practitioners. However, the initial vision was to develop 'a framework which is effective in quality assuring and benchmarking the skills of DwSIs' (Department of Health/FGDP UK, 2004). There is currently no widely agreed methodology for up-skilling general dental practitioners to enable them to achieve the competencies required for validation as outlined in these documents. The true workforce gap for this discipline of dentistry is yet unknown; however there is general acceptance of need for up-skilling the general dental workforce (Ghotane *et al.,* 2015) due to the impending release of the commissioning guide for restorative dentistry (NHS England, 2015a). The department of health imitated the medical model, and introduced the concept of dentists with special interests in a number of dental specialties including endodontics as described in the back ground to this this novel training initiative as described in section 1.2.

2.3.3 Current Training of the Workforce

Under European Union regulations, dentists undertake a five-year undergraduate training programme to enable them to enter the GDC register and allow them to register and practice as a dentist in the UK (Cowpe *et al.,* 2010). All undergraduate programmes are quality assured (General Dental Council, 2015b). On qualification, dentists undertake vocational training / foundation training (COPDEND website for Dental Foundation Programme). On graduation, these dentists are considered 'safe beginners', which is defined by the GDC as 'a rounded professional who, in addition to being a competent clinician and/or technician, will have the range of professional skills required to begin working as part of a dental team and be well prepared for independent practice, they will be able to assess their own capabilities and limitations, act within these boundaries and will know when to request support and advice' and able to perform independent practice described as 'working with autonomy within the GDC Scope of Practice, and own competence, once registered' it is noted that 'independent practice does not mean working alone and in isolation, but within the context of the wider dental and healthcare team, and may be under supervision if newly qualified' (General Dental Council, 2015a). Subsequently, they have the opportunity to complete postgraduate dental education and/or continued professional development to remain lifelong learners (General Dental Council, 2008; Boyle, 2011). Root canal treatment is part of the undergraduate curriculum (de Moor *et al*., 2013; Qualtrough, 2014).

Endodontics forms part of the government-funded speciality training pathway in restorative dentistry (Nayee *et al.,* 2014), but can also be studied as a National Institute for Health Research (NIHR)-funded or self-funded mono-speciality training pathway (Specialist Advisory Committee in Restorative Dentistry, 2009; Specialist Advisory Committee in Restorative Dentistry, 2010; National Institute for Health Research, 2016). Both pathways are limited by National Training Numbers (NTNs), without which completion of training does not automatically allow entry into the GDC specialist lists. A smaller number of non-NTN training posts are available for self-funded training; however equivalence must be demonstrated to the GDC for consideration of entry to the specialist lists after completion of such training via mediated entry. Those who have undergone government-funded pathways are trained to work as consultants in secondary care or academics in dental institutes. Many who have undertaken a self-funded approach to enhancing skills is likely to work within the private sector in order to recuperate the tuition fees and loss of earning during training. Therefore neither is likely to enter the general NHS primary care workforce. Secondary care, although considered NHS service delivery, is also tightly budgeted with strict acceptance criteria, which allow the service mainly to treat cases of high complexity. This is likely to leave some patients unable to access NHS treatment in a primary care setting and yet not be able to fulfil the criteria to access treatment from a secondary care setting.

2.3.4 Future Training of the Workforce

In their time, PCTs were under the burden of meeting patient demand with general dental practitioners with appropriate skills to meet the demands. The London Deanery was keen to provide the workforce by improving skills of dental practitioners. Both aiming at enabling patients in 'their patch' have access to high quality dental care as quality and outcomes of treatment are becoming increasingly important in healthcare (Darzi, 2008; Steele, 2009, Campbell & Tickle, 2013a; Tickle & Campbell, 2013; Campbell & Tickle, 2013b). Education is often seen a means to improving quality of healthcare and as a result, rising significance being placed on the quality of teaching and learning (Bloom, 1956; Darzi & Mackay, 2001; Fox, 1983; Mackay *et al.,* 2001). This philosophy has continued with the new NHS structure with NHS England working closely with Public Health England and Health Education England to maximise a workforce that is fit for purpose (Health and Social Care Act 2012, Health Education England 2014/15, Health Education England Framework 15). The most efficient use of resources to upskill the existing workforce, without significant reduction in the services that can be provided during training, is the ideal.

2.3.5 NHS Policy on Provision of Dental Treatment

The NHS is one of the largest healthcare organisations in the world that cares for the population it serves on the basis of need and not on the ability to pay. Whilst it is free at the point of delivery, it is funded by taxes and National Insurance contributions. In the UK, there are four healthcare systems demarcated by the four countries making up the UK: England, Scotland, Wales and Northern Ireland (Bevan *et al*., 2014a). In England, healthcare is the responsibility of Central Government, whereas in Scotland, Wales and Northern Ireland, it is the responsibility of the respective devolved governments. Services are provided differently in the four states depending on the health needs of each population, with slight differences in the challenges faced by all four (Grosios *et al.,* 2010; Timmins, 2013; Bevan *et al.,* 2014b). NHS dentistry is not free at the point of delivery for all, as the majority of adults are required to make co-payments for primary care dentistry. It has been reported that 70% of people in the UK believe that dental services are good and 65% believing that they have easy access to dental services, which is approximately 20-25% lower than people in Sweden, France and Germany (Boyle, 2011).

The NHS was developed in 1948, at a time of limited dental options and rampant dental disease (Steele, 2009; Grosios *et al.,* 2010). The demand was therefore high, but as a result of the fee-per-item of treatment made to the dentist, the government costs were also high. Between the first and second adult dental health surveys, the patterns of disease changed, with reduction in the number of people who had their teeth extracted and increase in the numbers of people who had their natural teeth filled instead (Gray *et al.,* 1970, Todd & Walker, 1980). By the end of the 1980s, dental decay in children and young adults fell and stabilised (O'Brien, 2004; Todd & Lader, 1991). Despite the changes in dental health patterns, the NHS system remained the same, with an emphasis on exactions and providing fillings, leading to a change in contract to emphasise continuing care with the introduction of capitation (Department of Health and Social Security, 1986).

The NHS General Dental Services was established with general dental practitioners (GDPs), working in their own practices (therefore as independent contractors), providing general dental care for the population through a mixture of NHS and privately funded means. Dental specialists treated particularly complex cases within hospital settings (secondary care). Community Dental Services (CDS) provided treatment for groups of patients with special needs; these dentists were employed by the Local Health Authorities and were paid an annual salary. The quality of dental treatment was assessed via the Dental Practice Board (DPB) who examined a sample of patients to detect poor quality or necessary treatment and to verify that the treatment claimed for payment has actually been provided (House of Commons Health Committee 2008a). It was not until 2002, when major policy change arrived with prevention high on the agenda and NHS Dentistry: Options for Change was published (Department of Health, 2002).

This led to the largest contract reform in primary care NHS services, with a shift of power to the Primary Care Trusts to ensure that the patients within their catchment area were given choice over their own care and outcomes were to be measured by their impact on patients (Department of Health, 2005a). In dentistry, this was closely followed by the 2006 reform of the dental contract changing the way dentists were paid to ensure the reduction in over treatment and escalate the prominence placed on prevention (NHS England, 2005a). Payment by results was introduced into secondary care; however there was a move in primary care to focus on prevention and health promotion rather than treatment of disease with the introduction of the UDA to replace the payment of a fee per item of treatment provided.

Prior to this, patient charges had first been introduced in 1951 with a proportion of the fee still paid by the NHS to the dentist. A revised contract was established between the Department of Health and dentists, where registration for adult patients and Capitation for children were introduced in 1990 (House of Commons Health Committee, 2008b; Steele, 2009). The remuneration was dependent on the treatment provided and therefore dentists were paid a fee per item of treatment. This was considered insufficient incentive to provide care and advice relating to prevention of dental disease as it promoted the provision of complex treatment thereby earning higher fees. As a result, the government were keen to improve access to NHS dental care and change NHS dentistry to better serve the population as stipulated in The NHS Plan (Department of Health 2000a, 2000b) and NHS Dentistry: Options for Change (Department of Health 2002).

The most recently introduced Dental Contract (2006) tried to steer away from active treatment to a greater emphasis on prevention. It was envisaged that there would be improvements to patient experience and clinical quality (House of Commons Health Committee, 2008a). The fees were simplified into three bands: Band 1: Examination, X-rays, advice on prevention (1 UDA), Band 2: Fillings (up to six), root canal work, extractions (3 UDAs), Band 3: Full dentures and Crowns, Bridges (12 UDAs), in addition additional UDAs were possible for other items such as urgent treatment (1.2 UDAs) and issue of a prescription (0.75 UDAs), and therefore the system changed from a fee-per-item to payment for an agreed level of annual service delivery. This UDA contract came into force in 2006 with piloting from 1998 to 2006 in Personalised Dental Services (PDS) although there was only evidence of treatment activity reducing, without evidence of prevention and associated benefits (Department of Health, 2002, 2005b; NHS 2005a). The methodology for measuring of dental activity was not piloted or tested (Steele 2009). This contract gave PCTs more power to commission the dental services needed for their population (House of Commons Health Committee 2008a). There was a small reduction in capacity as 4% of dentists chose to exit the NHS system and move into private care, exacerbating the problem of access.

Over the past decade, NHS policy has changed considerably. The Darzi report (2008), *High Quality Care for All*, brought into focus the need for promoting health as well as treating illness (with every PCT commissioning comprehensive wellbeing and prevention services), the idea of patients having choice in healthcare, improving quality of care (safer care, measure and publish information about the quality, linking funding for hospitals to quality of care), rewards for innovation, and improving the quality of NHS education and training. Around the same time, the House of Commons Health Select Committee investigated NHS dental services and raised issues including quality, quality assurance mechanisms and access to treatment (House of Commons Health Committee 2008a). The recommendations included the need for a better understanding of the problems and piloting of initiatives before full implementation.

The Steele Report (2009), *NHS Dental Services in England,* followed as a result by focussing on the problems of primary care dentistry within the NHS emphasising the vision for a future NHS, strengthening the view of better access, choice and high quality care. The idea of a staged pathway for commissioning and delivering dental care, using oral health as an outcome measure was introduced. This would allow patients to remain registered with their dentists and maintain the relationship, or dip in and out of the services as required without an impact on the quality of service and care they receive. Strong clinical guidelines and patient pathways would allow costly and complex care to be targeted at patients where they will be of greatest benefit. Root canal treatments have remained part of the pathway, subject to certain conditions being met. In order to push forward the quality, it was suggested that the free replacement period for restorations should be extended to three years (Steele, 2009). For the first time, incentives that blend rewards for activity and quality were suggested with actual measures of oral health outcomes and the outcome of treatment provided being considered. It was recommended that high priority be given to the development of consistent quality measures and routine collection of such data (Department of Health, 2010a).

The Steele report (2009) made way for a piloting of new clinical pathways based on managing risk and creating a healthy oral environment (Department of Health, 2010a, 2014b). The aims were also to explore new remuneration models focussing on quality of care over quantity of treatment. The findings from these pilots were published in two parts: patient and practitioner views (Department of Health, 2012) and learning after two years (Department of Health, 2014b). Three designs were piloted with remuneration methods being the only main difference. All were 'capitation based, of having a quality element, of conferring a responsibility for long term care of the patient on the contract holder and of being based on an oral health assessment and pathway' (Department of Health, 2012). All patients were initially seen to make an Oral Health Assessment (OHA) that informed the future pathway (or Self Care Plan) for the patient forming a traffic light system based on a red/amber/green rating (Department of Health, 2014b). The result of these pilot systems were an overall reduction in access as the number of patients seen by most of the pilot practices fell due to the additional time needed to achieve the clinical outcomes (Department of health, 2014b). The impact of the pilot programmes on endodontic treatment is likely to be the inability to provide complex care such as root canal treatment for those who failed to take responsibility for dental disease and therefore were unsuccessful in managing their primary disease (such as caries and periodontal disease). The advantage of this approach is avoiding the provision of resource heavy treatment on patients who would fail to shift their level of risk of dental disease to a safe level, thereby causing the failure of the treatment provided due to primary dental disease. This will focus resources on the teeth that are likely to have a good long-term outcome in a favourable oral environment. The consequence to endodontic services is a potential reduction in demand, allowing high quality care to be provided to low risk patients reflecting value for money (Steele, 2009).

In April 2013, the structure of the NHS changed dramatically, with the phasing out of Strategic Health Authorities (SHAs) and PCTs, establishing one large authority, NHS Commissioning Board, now named NHS England, with patient choice and quality of care taking centre stage (Department of Health, 2010b). NHS England was to closely work with National Institute for Health and Care Excellence (NICE), Health Education England (HEE), Public Health England (PHE), Care Quality Commission (CQC) and Health Watch England. The majority of the NHS budget for hospital services was given to the newly developed Clinical Commissioning Groups (CCGs), which were heavily influenced by General Medical Practitioners (GPs). Dentistry remained commissioned by NHS England through Area Teams, and Care Pathway Commissioning Frameworks that focus on quality were to be developed. One of the main spotlights of the developments was on consistently measuring clinical outcomes; quality standards and patient reported outcomes on the backdrop of financial constraint (NHS Commissioning Board, 2013; McDonald *et al.,* 2010; Boyle, 2011; Timmins, 2013; NHS England, 2013).

In 2014, the NHS Five-Year Forward View was published (Department of Health 2014a). The key themes described were prevention and public health, patients gaining more control over their own care, breaking down barriers on how care is provided with choice of radical new care delivery options such as the introduction of multispecialty community providers of out-of-hospital care and combining primary and acute care systems. All of which were needed to manage demand, efficiency and funding, as the NHS deficit was estimated to be £30 billion by 2020/21 (Department of Health, 2014a). In keeping with the trend towards removing obstacles between hospital and dental care in the community, this study was an opportunity to examine some of these aspects of service delivery across primary and secondary care.

2.4 Measuring Outcomes of Education & Training in Dentistry

Historically, much of dentistry as with much of healthcare has had a limited evidence base. We are now in a time where medicine and dentistry are heavily encouraged to be evidence-based with a view to improving the standards and outcomes of healthcare (National Institute for Health and Care Excellence 2014, 2015; Department of Health 2013a). The quality of evidence available for many dental procedures is seen as low or non-existent (Faggion, 2012). Teaching and learning in dentistry has, and still does, involve the trainee being given instruction from a more experienced trainer. Although in the past these techniques were often those that have 'worked' for the trainer, now there is a move for research informed care. Since the acceptance of evidence based dentistry, attention has turned to quality. It was Lord Darzi's report 'High quality of care for all' that received significant media coverage emphasising quality (Darzi, 2008), forcing a higher degree of scrutiny of the quality of care within the NHS. This has reignited a debate about competence of dental practitioners (Plasschaert *et al.* 2005, Cowpe *et al.,* 2010). Much of the debate has been focussed around medical practice; however certain aspects can be applied to dentistry (Centre for Workforce Intelligence 2014; NHS Commissioning Board, 2013; General

Dental Council, 2011). Highly experienced dental practitioners may be investigating the outcome of their treatment and publishing good results, but are other dental practitioners achieving the same high standards and are they getting the same outcomes?

2.4.1 Theories in Education

There are numerous theories in education, which are ever evolving. One of the earlier theories, behaviourism, assumes learning can be observed and is dictated to by the environmental conditions. Some consider students as learning through behaviourism where reinforcement of particular actions would result in more (with positive reinforcement) or less (with negative reinforcement) willingness to repeat the action (Skinner, 1953; Skinner, 1954).

Other educational theories consider the need for cognitive abilities to process, organise and understand information (Piaget, 1972; Piaget, 1973). This assumes the need for physical cognitive structures to assimilate new information and to accommodate or make sense of new experiences, therefore students test their internally constructed knowledge against what they experience, either discarding, modifying or (re) constructing their understanding to make sense of their own experience (Piaget, 1972; Piaget, 1973). A 'scaffolding' support structure is often suggested to allow students to access information at a level appropriate to their current understanding (Bruner, 1960; Bruner, 1996). It is recommended that teaching be organised, structured to allow students to make links between earlier and later periods of learning (Bruner, 1960; Bruner, 1996). This makes knowledge and understanding unique to the individual, as it is dependent on their own experiences, and therefore it is not assumed that 'teaching' will lead all students to the same knowledge and understanding.

Some have suggested that this theory can be applied to adult learning and that adults have significant prior learning, which should be built upon, but they also require 'safe' and collaborative environments to learn effectively. It is also recognised that there needs to be intrinsic motivation and they need to see the practical relevance of what they are learning (Knowles, 1973; Knowles, 1984). Experiential learning forms the basis for reflection as an instrument of enhancing self-learning (Dewey, 1938; Rogers, 1969). Situated learning considers the place where learning occurs and proposes that much of learning takes place collaboration and social interaction with other practitioners (Brown *et al.,* 1989).

Bloom's Taxonomy (Bloom, 1956) of cognitive learning domains have been revised in ascending order of difficulty to be remembering (easiest), understanding, application, analysing, evaluating and creating (most difficult). There are also affective domains (such as attitudes of professionalism), which requires information to be received, responded to, valued, organised/conceptualised and then internalised or adopted. Practical and 'thinking' skills are considered within the psychomotor domains and require imitation, manipulation, precision, articulation and naturalisation (Anderson *et al.,* 2001). Learning objectives, which are now widely accepted as necessary for good teaching use the verbs and nouns from this complex learning, teaching and assessment taxonomy by Anderson *et al.* (2001). These are simplified and summarised in Table 3.

Students learn in diverse ways, partly because of their individual learning styles and partly as a result of the context of the learning (Newble & Entwistle, 1986). Learning styles have been described in terms of 'surface', 'deep' and 'strategic', each causing in a different learning outcome (Newble & Entwistle, 1986). 'Surface' learning is identification of information considered important by the student and memorising these facts and ideas. In contrast 'deep' learning is described as seeking out meaning, examining evidence, relating the new ideas presented with previous knowledge and personal experience. 'Strategic' learning is the use of deep and surface approaches by some students depending on which approach they felt would produce the most successful results (Newble & Entwistle, 1986). Deep learning has been found to lead to better understanding and improved recall of facts immediately and several weeks later (Marton & Saljo, 1976; Svensson, 1977). A tendency towards deep and strategic learning has been demonstrated in post-graduate medical students (Samarakoon *et al.,* 2013).

Table 3: Revised Bloom's Taxonomy of Learning Domains

Cognitive Domains	Affective Domains	Psychomotor Domains
Remembering: recall or recognition of information	**Receive:** willingness to hear, open to experience	**Imitation:** observe and replicate
Understanding: interpret, extrapolate, translate in to own words	**Respond:** react and participate	**Manipulation:** reproduce action from instruction or memory
Application: apply knowledge to practise	**Value:** express personal opinions and attach value	**Precision:** execute skill independently and reliably
Analysing: interpret, organise, structure, consider the quality of elements	**Organise or conceptualise values:** develop vale system, reconcile internal conflicts	**Articulation:** adapt and integrate expertise
Evaluating: making judgments **Creating:** forming novel, coherent, original products	**Internalise or characterise values:** adopt belief system and philosophy	**Naturalisation:** automated unconscious mastery

Anderson *et al.* 2001

Learning is likely to be affected by the motivations to learn (Pintrich, 2003). The motivation for learning was recognised long ago as being extrinsic or intrinsic (Morstain & Smart, 1974; Misch, 2002; Abela, 2009). Surface learning may be driven by financial incentives, vocational incentives, or pressures from peers or in this case even from patients, due to impending assessments or due to the learning environment (Newble & Entwistle, 1986; Lizzio *et al*., 2003). The motivators for deep learning may be intrinsic and due to an inherent desire to gain a sense of mastering, there may be interest and curiosity in the subject, and there may be role models in the subject area (Newble & Entwistle, 1986; Lizzio *et al.,* 2003). The latter are usually linked with effective, long-term learning; however it is recognised that some external motivators can encourage an intrinsic approach to learning (Vansteenkiste *et al.,* 2006). The 'strategic' learners identify what they need to learn before beginning, hence focussing on the product of learning rather than the process.

They use whatever means necessary to achieve a successful result as they are motivated by competition and achieving high grades (Entwistle & Ramsden, 1983; Newble & Entwistle, 1986).

In order to achieve the learning objectives described by Bloom (1956), Fox developed theories of teaching, which include transferring of theory, shaping of thinking, building on transferring and shaping, travelling through the subject matter with the teacher as a guide and growing or nurturing of the student (Fox, 1983). Transferring and travelling is subject focussed, but shaping and growing is student focussed. In order to assess learning, the use of constructive alignment between teaching and assessment was developed via a portfolio experiment (Biggs & Tang, 2011). Following this, portfolio based assessment was formed in which the students were asked to put together evidence to show that the professional decision making has been improved by the theory that they have been taught. Learning objectives need to be mirrored in the teaching and the assessment should compare the student to the intended learning outcomes. Assessments should ideally test a performance or demonstration of understanding. The learning environment needs to be created by the teacher to achieve this goal, including learning activities, which reflect the learning outcomes. The grading system can be qualitative or quantitative and should be assessing the student against the stated criteria, not against other students (Biggs & Tang, 2011). Assessments can be formative or summative. Interim assessments benefit from being formative, as feedback can be used for deeper learning. Summative assessments may deter students from admitting errors or learning from errors, and they may also learn only what they think will be tested in the assessment. The students need clear guidance on what assessments are formative and summative during their learning (Biggs & Tang, 2011). All assessments are aimed at measuring behavioural change, however should not impede the development of an intrinsic change in the student.

2.4.2 Methods of Education Used in Dentistry

Education is at the heart of improving competence and in turn the quality of dentistry. Undergraduate dental education may involve many teaching and learning methods including didactic teaching; problem based learning and hands-on teaching in phantom head and clinical environments. Postgraduate education in dentistry tends to use fewer methods and can vary from distance learning courses mainly using printed educational materials, part time courses with or without hands-on components; to apprenticeship style work based learning. Hands-on post-graduate courses have been considered the most effective method of teaching dentists techniques in restorative dentistry (Maggs-Rapport *et al.,* 2000).

There are Cochrane reviews (Freemantle *et al*., 2005; O'Brien *et al*., 2007; Jamtvedt *et al*., 2006; Ivers *et al*., 2012; Ivers *et al*., 2014) on the effect of various methods of continuing education on professional practice and health care outcomes. Printed educational materials were said to make small improvements in professional practice when nine studies were assessed for change in provider behaviour and five studies on patient outcomes. Benefits of printed educational materials varied from -3% to 243.4% for change in provider behaviour and from -16.1% to 175.6% for patient outcomes. None were statistically significant at the 95% level (Freemantle *et al.,* 2005). When six studies were used to compare the impact of printed educational materials alone with educational materials combined with a further implementation intervention such as audit and feedback, the findings were mixed (Freemantle *et al.,* 2005). When thirty-two randomised controlled and quasi-experimental studies including between 13 and 441 health professionals were assessed, didactic teaching alone was considered unlikely to change professional practice but interactive workshops could lead to moderately large changes in professional practice (O'Brien *et al.,* 2007). Audit and feedback has also been researched resulting in the conclusion that audit and feedback can be effective especially when "baseline adherence to recommended practice is low and intensity of audit and feedback is high" (Jamtvedt *et al.,* 2006). This Cochrane review included 72 studies comparing any intervention with audit and feedback to no intervention, resulting in compliance with desired practice varying from a 16 % absolute decrease in compliance a 70% increase in compliance (Jamtvedt *et al.,* 2006). Another Cochrane review (Ivers *et al.,* 2012) analysed 140 randomised trials, showing that an absolute increase in healthcare professionals' compliance with the desired practice occurred about 4% of the time, and the effectiveness of audit and feedback depends on the baseline performance (better if baseline is low) and how feedback is provided. Written and verbal feedback together was more effective than alone and when delivered by a supervisor or senior colleague rather than an unknown person. Behaviour change was said to be most likely if feedback is accompanied by comparison with a behavioural target and by action plans (Ivers *et al.,* 2012; Ivers *et al.,* 2014).

Simulated learning of technical skills can be as effective in dentistry as bench top learning (Clancy, 2002). Newer Virtual Reality (VR) techniques showed promising results with VR appearing to be as good as traditional training on typodont teeth (Jasinevicius *et al.,* 2004; LeBlanc *et al.,* 2004). There is also a new trend for continuous learning by reflective thinking, where the individual examines an experience leading to a change in conceptual perspective (Boyd & Fales, 1983). Portfolios are often used for reflective learning as they record experiences and allows for discussion with trainers and mentors (Buckley *et al.,* 2009; Dennefer & Henson, 2007). There is little conclusive evidence regarding which method of teaching in dentistry improves technical skills. This may be due to the lack of usable tools to measure technical competence.

2.4.3 Assessment in Dental Education

In an article by Darzi & Mackay (2001), surgical care was described as having four components: diagnosis, plan of treatment, technical performance, and post-operative care. A surgeon's technical skills were said to be at the centre of surgical practice and technical performance was further segmented to surgeon's judgement which was described as "decision making that takes place during a surgical (or other) procedure" (Darzi & Mackay, 2001), knowledge, and dexterity. This description of technical skill can also be applied to dentistry. Assessment of technical performance is difficult and "needs to include a range of competencies necessary for carrying out a procedure effectively" (Darzi & Mackay, 2001). The authors stated that written examinations can be standardised and objective, but can be limiting in scope or depth and mainly focus on factual knowledge; viva voce examinations can be used to explore topics to greater or lesser depth but are a potentially threatening process which may disadvantage some candidates; and objective structured clinical examinations (OSCEs) can be standardised and objective using established objective criteria and marking schemes but the depth of assessment is limited. None of these methods are particularly useful in objectively measuring technical skill. Retrospective reporting from trainers is currently used for technical assessment and this can be subjective, poorly standardised and poorly validated.

Darzi and Mackay (2001) describe several other methods that have been developed to objectively assess technical skill: *The Objective Structured Assessment of Technical Skill (OSATS)* allows the candidate to perform a standardised task while being observed by at least two examiners. The examiners use two marking systems – a checklist (marked yes/no) and a global scoring sheet (marked 1-5, where 1=poor, 3=average and 5=excellent and examples of these marks are given to the examiners as guidelines). The checklists are specific to the task and must be validated. The global score assesses generic aspects and is "a more effective discriminator between subjects than checklists" (Regehr *et al.,* 1998; Darzi & Mackay, 2001). The OSATS measure knowledge and manual dexterity but not judgement. *The Imperial College Surgical Assessment Device (ICSAD)* uses computer software to analyse hand motions. Trackers are attached to the dorsum of the hand and the hands are moved within a magnetic field. This analyses the position of the hands while carrying out standardised tasks, but again judgement is not analysed. *The Minimally Invasive Surgical Trainer Virtual Reality (MIST VR)* developed in Sweden was the first attempt into using virtual reality for training and assessment. The initial results were said to be disappointing (Smith *et al.,* 1999) but virtual reality is still experimental technology and has potential for objective assessment of technical ability.

As most assessment methods appear to have strengths and weaknesses, it is accepted as good practice that more than one method is used (Mackay *et al.,* 2001; Mattheos *et al.,* 2009). Workplace Based Assessment has been developed to form an overall profile of a trainee and should compare their skill, knowledge and behaviour against those identified in the college's curriculum, which has been approved by the Postgraduate Medical Education and Training Board (General Medical Council, 2010). There are moves to introduce a similar system for dentistry.

2.4.4 Outcome of Root Canal Treatment

The gold standard for root canal treatment is described in Table 4. Hülsmann *et al.* (2005) described the goals of mechanical root canal preparations as

- Removal of vital/necrotic tissue from the main canal system
- Creation of sufficient space for irrigation and medication
- Preservation of the integrity and location of the apical anatomy
- Avoidance of iatrogenic damage to the canal system/root structure
- Facilitation of canal filling
- Avoidance of further contamination of the periradicular tissues with irrigants/infection
- Preservation of sound root dentine

These goals are based on those first described by Schilder (1974) where importance was placed on continuous tapering of the canal from the apex to the access cavity with the cross sectional diameter of the canal being narrower at every point apically, the root canal treatment following the shape of the original canal maintaining the apical opening as small as possible and maintaining the apical foramen in its original position. This was in order to maintain the biological objectives of confining the instrumentation to within the root canal, removal of all of the tissue from the root canal space, creation of sufficient space for intra-canal medicaments and not forcing necrotic and potentially infected debris beyond the foramen (Schilder, 1974). The variability of an ideal tapered shape of a canal may assume less significance in the future with more widespread use of rotary instrumentation.

The measure of outcomes depends upon the perspective of those measuring it. Outcomes of root canal treatment have previously been studied and assessed by clinicians and researchers using radiograph, clinical signs and symptoms (Friedman, 2002; Ng *et al.,* 2007). It would be neither practical nor ethical to have histological sections, although these would allow definite outcomes of healing to be assessed.

Patients are likely to measure outcome in relation to the absence of symptoms (Bender *et al.* 1966a; 1966b), function and aesthetics (Friedman & Mor, 2004) and overall quality of life (Dugas *et al.,* 2002). Symptoms may be subjective from the patient's perspective and signs can be subjective from the clinician's perspective. The only objective clinical sign would be the presence of a sinus or well-demarcated swelling prior to treatment and the absence of a sinus or well demarcated swelling following treatment. This presence or absence of clinical signs and symptoms are easily collected provided that the clinician records this information.

Table 4: Summary of the gold standards for root canal treatment, as described by the European Society of Endodontology (2006)

Pre-op radiograph:	Show at least the full length of the root and approximately 2-3mm the periapical region
Local anaesthesia	Should be considered and given as appropriate
Preparation of the tooth:	All caries and defective restorations removed, and if required, the occlusion adjusted and tooth protected against fracture
Isolation:	By the use of rubber dam
Access cavity preparation:	Remove roof of pulp chamber, enable root canal instruments to enter canal without undue bending and offer sufficient retention for a temporary restoration, conserving as much sound tooth structure as possible.
Determining the working length	Use electronic and radiographic methods to determine working length (should be as close to the apical constriction as possible – i.e. between 0.5 and 2mm of the radiographic apex). It may be necessary to take more than one working length radiograph.
Preparation of the root canal system	The prepared canal should include the original canal, the apical constriction should be maintained, the canal should end in an apical narrowing, the canal should be tapered from crown to apex
Irrigation	The irrigant solution should preferably have disinfectant and organic debris dissolving properties, should be delivered in copious amounts as far up the canal as possible without risking extrusion beyond the foramen, and may be delivered by ultrasonic or sonic systems
Inter-appointment medication	Should be used following proper cleaning and irrigation and to support the tissue dissolving effects of the irrigating solutions. The medicament used should have long lasting disinfection properties, be biocompatible, removable and non-damaging to the tooth structure or restorative material. An effective temporary restoration is essential to prevent contamination of canals between visits This stage is not necessary in vital cases
Obturation of the	Materials used to fill the canals must be biocompatible, dimensionally stable, able to seal, unaffected by tissue fluids and insoluble, non-

root canal system	supportive of bacterial growth, radio-opaque, and removable from the canal if re-treatment is needed. A sealer must be used to fill the voids between a semi-solid filling material and the walls of the canal. Sealers containing organic materials such as aldehydes are not recommended. Filling should be done after completion of canal preparation (when the canal is thought to be free of infection and can be dried) and after a radiograph verifying the preparation has been taken. The quality of the filling must be checked with a radiograph which should show the root apex and preferably 2-3mm of the periapical region. The filled canal should be completely filled unless a post space is required and contain the original canal. No space should be seen between the canal filling and the canal walls. There should be no canal space visible beyond the end point of the root canal filling.
Assessment of outcome of root canal treatment	Should be assessed at least after 1 year and subsequently as required. Favourable outcome: absence of pain, swelling and other symptoms, no sinus tract, no loss of function and radiological evidence of a normal periodontal ligament around the root. Uncertain outcome: periapical lesion remains the same size or has only reduced in size. In this situation it is recommended that the lesion is further monitored for a minimum period of 4 years. If the lesion persists, the tooth may be associated with post-treatment disease. Unfavourable outcome: tooth is associated with signs and symptoms of infection, a radiologically visible lesion has appeared subsequent to treatment or a pre-existing lesion has increased in size, the lesion has remained the same size or only diminished in size during the 4 year assessment period, or continuing root resorption is present. *Exception: the presence of scar tissue – an extensive radiological lesion may heal but leave a locally visible, irregularly mineralised are. This tooth should continue to be assessed.*

European Society of Endodontology, 2006

Insurance companies and dental public health bodies would be inclined to ascertain the retention or survival of the tooth following root canal treatment (Lazarski *et al.,* 2001; Caplan *et al.*, 2002; Salehrabi & Rotstein, 2004; Lumley *et al.,* 2008; Tickel *et al.,* 2008; Chen, 2007; Ng *et al.,* 2010). These studies do not address the quality of treatment or the clinical signs and symptoms but only assess the presence or absence of further treatment or extraction of the tooth as the end point. They do not give any indication of the clinical or radiographic status of the tooth. Table 5 shows a summary of the findings.

Table 5: Survival rates in for root canal treated teeth

Study	No of teeth included	Years data collected	Survival rates	Country and type of service evaluated
Lazarski *et al.* 2001	109,542	1993-1998	94.4% at 3.5 years	USA Private practice of generalists & specialists
Salehrabi & Rotstein 2004	1,462,936	1995 - 2002	97% at 8 years	USA Private practice of generalists & endodontists
Chen 2007	1,557,547	1998	91.1% - 95.4% at 5 years	Taiwan Private practice
Lumley *et al.* 2008	30,843	1991-2001	74% at 10 years	UK (NHS) General dental practice
Tickle *et al.* 2008	174	1998 - 2003	90.8% at 5 years	UK (NHS) General dental practice
Ng *et al.* 2010	(Meta-analysis of 14 studies)		86% (95%CI:75%,98%) at 2–3 years 93% (95%CI:92%,94%) at 4–5 years 87% (95%CI:82%,92%) at 8–10 years	Mix of countries and settings (Review - pooled success)

Lazarski *et al.,* 2001; Salehrabi & Rotstein, 2004; Chen, 2007; Lumley *et al.,* 2008; Tickel *et al.,* 2008; Ng *et al.,* 2010

The reported survival of root canal treated teeth include 8-year survival of 97% in the United States (Salehrabi & Rotstein, 2004), 5-year retention rates of 91.1%-95.4% in Taiwan (Chen *et al.,* 2007), and 3.5-year survival of 94.44% in the United States (Lazarski *et al.,* 2001). In the UK there have been similar studies with 10-year survival rates of 74% in NHS General Dental Practice (Lumley *et al.,* 2008). These studies have not examined the quality of treatment provided or the state of the treated tooth in the mouth following treatment. The absence of further treatment of the tooth alone was deemed success. When success was assessed in UK, outcome of root canal treatment performed in the Royal Air Force had a significantly higher success rate of 85% using radiographic and clinical signs to define success and failure with the review period grouped into <3years and >3years since root treatment (Peak *et al.,* 2001).

A retrospective cohort study of patients (n=174) treated in NHS general practice (n=12) in the UK, on the survival of mandibular first permanent molars that were root canal treated within the state funded National Health Service also assessed the quality of the root fillings by the radiographic appearance of the root filling (Tickle *et al.,* 2008). A research assistant copied clinical notes, and radiographs were copied using a digital scanner. A trained nurse carried out the clinical notes using a data extraction form. Root canal treatments were assessed radiographically by an endodontist and deemed 'optimal' or 'sub-optimal' (in accordance with the Consensus report of the European Society of Endodontology on quality guidelines for root canal treatment, 1994) or the radiograph was classed as missing/unreadable. Training, calibration and reliability of this examiner were not reported. Healing as seen radiographically was not assessed. Failure was defined as extraction, replacement of the root filling or periradicular surgery performed on the tooth. The review period varied up to 7.7 years with <10% failure rate. Similar failure rates were seen in 'optimally filled', 'sub-optimally filled' and 'unreadable/missing radiographs' groups. The majority of the failures were within the first year following treatment. Root canal treated teeth restored with crowns had a lower risk of failure than those restored with intra-coronal restorations. It was assumed that these 'successful' teeth were free of signs and symptoms of infection and that is why they were not extracted, re-treated or surgically treated. This paper was considered controversial as it implied an acceptance of 'sub-optimal' root fillings, as survival rates were still high as long as prompt definitive restoration of the tooth is carried out (Chong, 2008; Hyatt, 2008).

Recent detailed and comprehensive systematic reviews by Ng *et al.* (Ng *et al.,* 2007, 2008a, 2008b) tried to collate the various outcome findings. Ng *et al.* (2007) looked at the effects of study characteristics on probability of success of primary root canal treatment. They used the presence or absence of clinical signs and symptoms as well as 'strict' (absence of apical radiolucency at recall) and 'loose' (reduction in size of apical radiolucency at recall) criteria for radiographic interpretation in describing success. Root canal treated teeth should be compared with what is described to be normal i.e. the lack of pain, swelling, sinus tracts, tenderness to palpation and percussion, tenderness in function and mobility (Friedman, 2002; Cohen & Hargreaves, 2006).

In a meta-analysis (Ng *et al.,* 2008a) which used both 'strict' and 'loose' criteria, estimated pooled success rates of primary root canal treatment was 74.7% (95%CI 69.8% - 79.5%) under 'strict' criteria and 85.2% (95%CI 82.2% - 88.3%) under 'loose' criteria has been reported. The review period varied from six months to thirty years. The idea that since technology and materials have improved over time, the success rates should also improve has been explored, but no supportive evidence was seen. It is thought that this lack of increase in success rate is as a result of 'more adventurous case selection fuelled by confidence in better skills and outcomes' (Ng *et al.,* 2007).

Root canal treatment carried out by postgraduate students and specialists had the highest weighted pooled success rate irrespective of strict or loose criteria being used to measure success (Ng *et al*., 2007). It has been said that educational background of the operator may have an impact on dentists' decision-making or case selection (Akeel, 2008; Dechouniotis *et al.,* 2010). Other studies have suggested that the background or experience of the operator can have an influence on the technical outcome of endodontic procedures (Gulabivala *et al.,* 2000, Van Zyl *et al.,* 2005). A clinical study by Alley *et al.* (2004) showed endodontic treatments by specialists were significantly more successful that that by GDPs. The difference in outcome between generalists and root canal is less clear in some studies for example of 29,895 non-surgical root canal treatments performed by non-endodontists 1,390 (4.65%) required subsequent retreatment or periradicular surgery. In comparison, of 14,718 non-surgical endodontic treatments carried out by endodontists, 597 (4.06%) cases required subsequent retreatment or periradicular surgery (Lazarski, 2001). Ng *et al.* (2007) highlight the lack of tools or methodology to objectively quantify operator skills; the need to balance between technical skill and 'understanding of the problem and the motivation and integrity with which the procedure is performed'. In terms of QoL, improvement in 'physical pain' and 'social disability' were significantly higher if treated by an endodontist than a generalist. The logistic regression model for 'predicting improvement in the ability to perform usual jobs' in this study predicted that the subjects are seven times as likely to perceive improvement in the ability to perform usual jobs when the treatment was provided by an endodontist than a generalist. The logistic regression model for 'predicting improvement in temperature sensitivity' showed that patients were 2.7 times more likely to perceive an improvement if the treatment was completed by an endodontist (Dugas, 2002). Hamasha and Hatiwsh (2013) used the same questionnaire used by Dugas (2002) and found no significant differences in the improvement of oral health between patients treated by undergraduates, postgraduates and specialists in some domains and improvements in favour of specialists in other domains. For example, satisfaction was higher when treated by a specialist in relation to 'time involved, intraoperative pain, pleasantness and general satisfaction' when compared to treatment by undergraduate students. However, there was least satisfaction with the treatment cost when compared treatment by postgraduate or undergraduate students (Hamasha & Hatiwsh, 2013).

Root canal treatment is described as 'primary root canal treatment' if it is the first time root canal treatment is provided for a tooth. If the root canal treatment is redone or revised, it is termed 'secondary root canal treatment'. In terms of root canal outcome in primary care versus secondary in the UK, the success rate of primary root canal treatment in one secondary care unit in the UK was 83% [95% CI: 81%, 85%] and that for secondary root canal treatment was 80% [95% CI: 78%, 82%] (Ng *et al.,* 2011a). The 4-year cumulative tooth survival rates for primary root canal treatment was 95.4% [95% CI: 93.6%, 96.8%] and that for secondary root canal treatment was 95.3% [95% CI: 93.6%, 96.5%] (Ng *et al.,* 2011b). For comparison no outcome data are available for the success of root canal treatments performed in primary care in the UK. The survival of root canal treated teeth has been estimated at 90.8% at five years (Tickle *et al.,* 2008) and 74% at 10 years (Lumley *et al.,* 2008). Since the introduction of UDAs in April 2006 (House of Commons Health Committee, 2008a), it is no longer possible to calculate the numbers of root canal treatments carried out in the NHS as this banding system groups together types of treatment rather than recording individual items of treatment.

Ng *et al.* (2008a) investigated the influence of clinical factors on the probability of success of primary root canal treatment. The review set out to examine the influence of numerous patient and operator factors. Four conditions were found to significantly improve the outcome of primary root canal treatment: pre-operative absence of periapical radiolucency, root filling with no voids, root fillings extending to two millimetres within the radiographic apex, satisfactory coronal seal.

Ng *et al.* (2008b) also carried out a similar systematic review on the outcome of secondary root canal treatment with a pooled weighted success rate based on ‘strict’ criteria of 76.7% (95% Confidence Interval of between 73.6% and 89.6%) and that based on ‘loose’ criteria of 77.2% (95% Confidence Interval of between 61.1% and 88.1%). The conditions for success were similar to those for primary root canal treatment. The success rates from studies carried out in the 2000’s were the lowest whether ‘strict’ or ‘loose’ criteria were used. Treatment carried out by specialists surprisingly had the lowest estimates of success regardless of the use of ‘strict’ or ‘loose’ criteria, which is thought to be as a result of specialists possibly managing more complex cases. The qualifications of the operator had no significant influence of the outcome of secondary root canal treatment. The weighted pooled success rate for teeth without periapical lesions pre-operatively was 28% higher than for those with pre-operative periapical lesions. The systematic reviews on outcomes of primary and secondary root canal treatment (Ng *et al.,* 2008a, Ng *et al.,* 2008b), both suggest that the size of pre-operative periapical lesions are not relevant as long as enough time is given for healing. The weighted pooled success rate for teeth without pre-operative perforation was 32% higher than that for teeth with pre-operative perforation. Root fillings extended beyond the apex had the lowest success rate regardless of the presence or absence of a periapical lesion. These results are summarised in Table 6. Due to lack of adequate data (Ng *et al.,* 2008a; Ng *et al.,* 2008b) a meta-analysis relating to many related aspects of root canal treatment was not performed. These aspects included the effect of canal obturation, the use of rubber dam, apical instrumentation, size of apical preparation, canal taper, separation of instrument during root canal treatment, medicament used, root filling techniques and materials, quality of root filling and number of treatment visits on the outcome of root canal treatment.

Table 6: Summary results from two systematic reviews

	Using 'strict' criteria	**Using 'loose' criteria**
Success rate of primary root canal treatment i.e. root canal treatment done for the first time in a tooth **(Ng *et al.,* 2008a)**	74.7% (95% Confidence Interval of between 69.8% and 79.5%)	85.2% (95% Confidence Interval of between 82.2% and 88.3%)
Success rate of secondary root canal treatment i.e. revision root canal treatment **(Ng *et al.,* 2008b)**	76.7% (95% Confidence Interval of between 73.6% and 89.6%)	77.2% (95% Confidence Interval of between 61.1% and 88.1%)

Ng *et al.,* 2008a; 2008b

Cheung & Chan (2003) investigated the survival of primary root canal treatment carried out by undergraduates and postgraduates in a dental hospital in Hong Kong using a retrospective longitudinal design. They found a 50% success rate at 9.2 years, with the survival of root-filled teeth being significantly influenced by the tooth type (maxillary and mandibular molar teeth fared worse than anterior and premolar teeth), preoperative periapical status (better if no area prior to treatment) and the type of coronal restoration (teeth with crowns survived significantly longer than those with intra-coronal plastic restorations only (Cheung, 2002; Cheung & Chan, 2003).

Ng *et al.* (2010) carried out a systematic review on tooth survival following non-surgical root canal treatment. Although fourteen studies were included (10 retrospective and 4 prospective), a direct comparison was hindered by the heterogeneity of the studies. The pooled percentage of reported tooth survival over 2-3yrs was 86% (95% CI: 75%, 98%), over 4-5yrs was 93% (95% CI: 92%, 94%) and over 8-10yrs was 87% (95% CI: 82%, 92%). In descending order of influence, the factors seen to be effecting survival were: a crown restoration after root canal treatment, the tooth having both the mesial and distal proximal contacts, tooth not functioning as an abutment for removable or fixed prostheses and tooth type (non-molar teeth). Similar findings have been supported by other publications (Caplan *et al*., 2002; Farzaneh *et al.,* 2004; Stoll *et al.,* 2005). The most recent publications from Ng *et al.* (Ng *et al.,* 2011a; Ng *et al.,* 2011b) relate the findings from a prospective study of the factors affecting outcomes of non-surgical root canal treatment. The findings are summarised in Table 7.

The assumption is that a well-condensed and well-extended root filling as seen radiographically may mean a job well done by a conscientious worker, with appropriate isolation, access, irrigation etc. However, it is not appropriate to always make this assumption. As previously discussed in section 2.5.4, published data suggests that a large percentage of general dental practitioners use endodontic techniques with no evidence of clinical effectiveness.

Whether success or survival rates are taken into consideration, it is clear that it is worth providing endodontic treatment to patients as success and survival rates are comparable to extraction and replacement of the space with a denture, bridge or implant. These alternatives have other disadvantages and a more significant maintenance cost.

Table 7: Summary of factors affecting outcome of non-surgical root canal treatment

<table>
<tr><th>Study</th><th>Success rates</th><th>Conditions found to improve periapical healing</th></tr>
<tr><td>Success rate of primary root canal treatment
(Ng et al., 2011a)</td><td>83%
(95% CI: 81%, 85%)</td><td rowspan="2">1. The pre-operative absence of periapical lesion
2. Presence of periapical lesion, the smaller its size
3. The absence of a pre-operative sinus tract
4. Achievement of patency at the canal terminus
5. Extension of canal cleaning as close as possible to its apical terminus
6. The use of EDTA solution as a penultimate wash followed by a final rinse of NaOCl in secondary root treatment cases
7. Abstaining from using 2%CHX as an adjunct irrigant to NaOCl solution
8. Absence of tooth/root perforation
9. Absence of inter-appointment flare-up (pain /swelling)
10. Absence of root filling extrusion
11. Presence of satisfactory coronal restoration</td></tr>
<tr><td>Success rate of secondary root canal treatment
(Ng et al., 2011a)</td><td>80%
(95% CI: 78%, 82%)</td></tr>
</table>

Ng *et al.*, 2011a

2.4.4.1 Assessment of Clinical Outcome

Assessment of outcome in root canal treatment is generally difficult due to subjectivity. In order to develop an objective assessment a number of variables need to be controlled. These can be separated into clinical, radiographic and patient related variables. In terms of clinical signs and symptoms, root canal treated teeth should be compared with what is described to be normal (Friedman, 2002). Signs of normal healing include the lack of swellings and sinus tracts. Symptoms of non-healing include pain, tenderness to palpation and percussion, tenderness in function and mobility (Cohen & Hargreaves, 2006). Clinical assessment of outcome is based on signs and symptoms.

Symptoms are subjective from the patient's perspective and some signs can be subjective from the clinician's perspective. For example, healing is often considered to have occurred if the symptoms of pain have resolved. However, teeth can lose vitality and root canal treatments can fail without any pain experienced by the patients (the problem being an incidental finding during a routine dental examination). In certain cases, there can be more pain following instrumentation and root canal retreatment (Glennon *et al.,* 2004; Ng *et al.,* 2011a). In these cases improvement in patient related symptoms is not the most appropriate method of assessing outcome. Additionally, there is obvious recall bias involved.

Similar testing for improvement in the signs of infection by tapping on a tooth or applying finger pressure on the buccal sulcus is subjective, depending on the pressure applied by the clinician and the pain threshold of the patient. These signs are reported usually as being present or absent as no further quantifying is possible. Often there is reliance on the patient to inform the clinician as to improvement in tenderness elicited by tapping a tooth or palpating the buccal sulcus. The only objective clinical sign would be the presence of a sinus or well-demarcated swelling prior to treatment and the absence of a sinus or well demarcated swelling following treatment.

It is also important that the presence or absence of pain, tenderness to percussion, swelling, sinus and tenderness to palpate the adjacent tissues is documented in the clinical notes. Ng *et al.* (2011a) found that the presence of pain or swelling following chemo-mechanical debridement significantly reduced the success of treatment (Ng *et al.,* 2011a). The presence of one or more of these signs will be indicative of continuing disease process in the majority of cases. However, there are instances where teeth continue to be painful in the absence of any other sign of disease following endodontic treatment and swelling can heal with scarring without the entire swelling disappearing. In the same way there are instances where there are signs and symptoms of disease clinically and yet radiographically an apical radiolucency is seen associated with the tooth.

2.4.4.2 Assessment of Radiographic Outcome

From pre-operative radiographs, it is possible to observe the number of canals in most instances, the position of the canals, the taper and even most obstructions within the canals. Taking radiographs during and post treatment allows visualisation of the position of the obturation within the canal, possibly missed canals, the apical extent of the root filling, the taper of the obturation, procedural errors etc. The shape of the access cavity and straight line access to canals may be difficult to assess clinically or from a post-operative radiograph as the teeth may have been restored with cuspal coverage restorations post treatment. To some extent straight line access may be assessed from working length radiographs. Gaining this information is very much dependent on the quality of the radiographs.

The apical extent of the obturation is a surrogate end point for the extension of instrumentation and success rates have often been correlated with the apical extension of the obturation (Ng *et al.,* 2008a; Ng *et al.,* 2008b; Ricucci, 1998). The recommendation is that instrumentation and obturation remain within the root canal (Cailleteau & Mullaney, 1997) and more precisely terminated at the apical constriction (Langeland, 1957; Langeland, 1967; Langeland, 1987). The apical constriction is the narrowing of the root canal in the apical third where it is thought the pulpal tissue contacts the periapical tissues. The cemento-enamel junction was once thought to be an indicator of the apical foramen, but this is a 'histopathological structure, which cannot be found clinically and thus, cannot be instrumented or obturated' (Ricucci, 1998). Roots may have numerous foramina, these may deviate from the long axis of the root and the apical constriction can be 0.20 – 3.80mm from the apex (Gutierrez & Aguayo, 1995). Radiographic assessment of the apical extent of the root canal obturation does not give an indication of the proximity of the obturation to the apical terminus (Ricucci, 1998). Although there is evidence for the poor correlation between the radiographic apex and the true position of the apical constriction, there is also evidence for improved success rates where instrumentation and obturation remains 1-2mm short of the radiographic apex (Ricucci, 1998). Electronic apex locators have been shown to be accurate at locating the apical terminus more frequently than plain film radiographs (Real *et al.,* 2011; Mosleh *et al.,* 2014) and also more accurate than cone-beam computed tomography *in vitro* (Lucena *et al.,* 2014).

Ørstavik *et al.* (1986) developed a periapical index (PAI) for the radiographic assessment of endodontically treated teeth; however, this cannot be used as a measure of success or failure. Asymptomatic unresolved periapical radiolucencies may occur for a variety of reasons including intraradicular infection in the apical root canal system, extraradicular infection (often periapical actinomycosis), cystic lesions, foreign body reactions to crystalline objects of endogenous origin (cholesterol crystals), extruded root canal filling materials or other foreign materials and the lesion being filled with scar tissue healing (Nair, 2006). Radiographic signs alone are not recommended for the purpose of assessing outcome as symptomatic teeth without radiographic signs may be judged as successful and asymptomatic teeth with radiographic radiolucencies may be deemed failures (Friedman, 2002).

Radiographic assessment involved a periapical radiograph taken of the tooth in question and assessed for the presence of disease, the extent and possibly the nature of the disease. The following is assessed in terms of healing following endodontic treatment (Strindberg, 1956; Ørstavik *et al.,* 1986):

(1) An intact lamina dura around the root(s) and

(2) The presence or absence of a radiolucent area associated with the root(s)

Assessment should be carried out under specified conditions. It must be understood that the radiograph is a 'two-dimensional picture made up of a variety of black, white and grey superimposed shadows' (Whaites, 2007). Plain film radiography has involved x-rays passing through the patient and interacting with the photographic emulsion on a film resulting in blackening of the film (Whaites, 2007). Digital radiography involves x-rays hitting a digital sensor leading to a computerised image where the areas it by the x-rays appear black (Whaites, 2007). In both cases the darkness depends on the number of x-rays reaching the film/sensor, which in turn is dependent on the density of the object being radiographed. One would therefore expect the densest part of a tooth to appear white and an apical infection to appear black on a radiograph (Picture 1), however the final image is affected by the following (Whaites, 2007):

- The specific type of material the object being radiographed is made out of
- The thickness or density of the material
- The shape of the object
- The intensity of the x-ray beam used
- The position of the object in relation to the x-ray beam and image receptor
- The sensitivity and type of image receptor
- The superimposition of the adjacent structures

For an ideal radiographic image, the object and image receptor should be in contact or as close together as possible, the object and image receptor should be parallel to one another and the x-ray tube should be positioned so that the beam meets both the object and the image receptor at right angles (Whaites, 2007). This however is not always possible in dental radiography especially during endodontic treatment as rubber dam clamps; endodontic files etc. are likely to prevent the film being in direct contact with the tooth. Table 8 summarises the optimum viewing conditions for various types of radiographic technique.

Table 8: Optimum viewing conditions

Radiographic technique	Optimum viewing conditions
Plain films (Whaites 2007)	• Even, uniform, bright light viewing screen preferably with variable intensity to allow viewing of films of different densities • A darkened viewing room • The area around the radiograph should be masked by a dark surround so that light passes only through the film • Use of magnifying glass to allow fine detail to be seen more clearly on intraoral films • The radiographs should be dry
Digital films (Sogur *et al.*, 2009)	High resolution (super video graphics array) colour cathode ray tube monitor with resolution of 1024x768 pixels using dedicated software for each digital system.
CBCT (Sogur *et al.*, 2009)	High-resolution (super video graphics array) colour cathode ray tube monitor with resolution of 1024x768 pixels using the dedicated software for system.

Different studies have used a variety of criteria ranging from the Strindberg classification (1956) based on the absence of periapical rarefactions on a radiographs, which was built upon by Ørstavik (1986). Ng *et al.* (2011a) assessed conventional plain films on a fluorescent light box under magnification of 2.5 in a darkened room. Their assessment separated the cases into 'intact periodontal ligament', 'widened periodontal ligament' (>0.5mm) and 'presence of a periapical lesion' (measured with a metal ruler to 0.5mm increments under 2.5x magnification). Table 9 summarises the radiographic appearance of various stages of apical inflammation as described by Whaites (2007).

Table 9: Effects of inflammatory processes on apical tissues and the resultant radiographic appearance (Whaites 2007)

State of inflammation	**Underlying inflammatory changes**	**Radiographic appearance**
Initial acute inflammation	Inflammatory exudate accumulates in the apical periodontal ligament space – *acute apical periodontitis*	Widening of the radiolucent line of the periodontal ligament space OR No apparent changes evident Loss of the radiopaque line of the lamina dura at the apex Area of bone loss at the tooth apex
Initial spread of inflammation	Resorption and destruction of the apical bony socket – *periapical abscess*	
Further spread of inflammation	Further resorption and destruction of the apical alveolar bone	
Initial low-grade chronic inflammation	Minimal destruction of the apical bone The body's defence systems lay down dense bone in the apical region	No apparent bone destruction but dense sclerotic bone evident around the tooth apex - *sclerosing osteitis* Circumscribed, well defined radiolucent area of bone loss at the apex, surrounded by dense sclerotic bone
Latter stages of chronic inflammation	Apical bone is resorbed and destroyed and dense bone is laid down around the area of resorption – *periapical granuloma* or *radicular cyst*	

The European Society of Endodontology recommends that post root canal treatment review is done at least 1 year following obturation of the canals (ESE, 2006). Their preferred definitions of success are described as 'favourable', 'uncertain' and 'unfavourable' outcome (Table 10). Ng *et al.* (2011a) showed that the majority of primary and secondary endodontic treatment healed completely within 2-3 years. Other studies (Ng *et al.,* 2008b; de Chevigny *et al.,* 2008a, 2008b) have shown that non-surgical root canal treated cases can continue to heal for up to 4-5 years.

Table 10: Definition of healing in endodontic treatment (European Society of Endodontology guidance 2006)

Healed **(Favourable outcome)**	**Healing** **(Uncertain outcome)**	**Failed** **(Unfavourable outcome)**
Absence of tenderness, pain, redness, swelling and other symptoms, no sinus tract, no loss of function, no tooth mobility And Radiological evidence of lack of radiolucency, a normal of periodontal ligament around the root with a normal width of periodontal ligament space	Periapical lesion remains the same size of has only reduced in size. (In this situation it is recommended that the lesion is further monitored for a minimum period of 4 years. If the lesion persists, the tooth may be associated with post-treatment disease)	Tooth is associated with signs and symptoms of infection, a radiologically visible lesion has appeared subsequent to treatment or a pre-existing lesion has increased in size, the lesion has remained the same size or only diminished in size during the 4-year assessment period, or continuing root resorption is present. (Exception: the presence of scar tissue – an extensive radiological lesion may heal but leave a locally visible, irregularly mineralised are. This tooth should continue to be assessed.)

There are alternative methods of assessing radiographic outcome (Patel *et al.,* 2009a). Wu *et al.* in 2009 highlighted the problems of using radiographs for evaluation of endodontic outcome. The issues raised were that the image on a radiograph represents a two dimensional image of a three dimensional object with the apical area being visible depending on the size of the lesion and the thickness of the cortical plates, as well as that issue that the change in size of lesion could not be determined clearly using radiographs as volumetric change (especially in a lingual direction) would require CBCT for calculation. It was suggested that there is an over estimation of endodontic success by as much as 30% when using radiography compared to CBCT. CBCT would be better at ascertaining the presence or absence of an apical area associated with the tooth, however only histological examination would be useful in establishing the true nature of the apical lesion (healing with scarring vs. infection). It is appreciated that apical periodontitis can be asymptomatic and periapical pathology can exist without apparent radiographic change (Lee & Messer, 1986).

Sogur *et al.* (2009) investigated the detectability of chemically induced periapical lesions in 12 dry human mandibles using limited CBCT, indirect intra-oral digital radiography and plain film radiography. It was found that limited CBCT had significantly higher sensitivity and specificity compared to plain film and digital radiography. However, as the size of lesion increased the difference in sensitivity and specificity reduced between the tree modalities. No significant differences were found between the digital and plain film radiographs for any of the lesion sizes (Sogur, 2009). Other studies have found similar results with CBCT outperforming conventional radiographs for identification of periapical periodontitis (Patel *et al.,* 2009b). The accuracy of intra-oral plain films with digital and enhanced digital radiographic images for length determination in root canal treatments found that all image types were of similar accuracy for file measurement (Woolhiser *et al.,* 2005). In animal models, when periapical radiography, CBCT and histology (using histology as the gold standard) were compared for the assessment of periapical periodontitis, the diagnostic accuracy was 0.78 for periapical radiography and 0.92 for CBCT with a statistically significant difference between the two (de Paula-Silva *et al*., 2009).

The use of CBCT for endodontics is becoming more popular (Peters & Peters, 2012) with the ability to construct endodontic guides to allow canal location (van der Meer *et al.,* 2016); however the dose of CBCT is still higher than conventional dental radiography, and routine use for information that is accessible from conventional lower dose radiography, is not recommended (AAE and AAOMR Joint Position Statement, updated 2015; Patel *et al.,* 2014). Patient movement during the scan and metal restoration/posts can cause scatter, limiting the usefulness of the images (Patel *et al.,* 2015). Although use of CBCT for the routine assessment of the outcome of root canal treatment is not recommended, some have justified its use of small field of view CBCT in clinical research trials where new treatment protocols and disinfection techniques are being assessed using healing outcomes, provided ethical approval is granted (Patel *et al.,* 2015). CBCT may be superior in its diagnostic accuracy in detecting apical periodontitis; it is difficult to justify exposing all patients for CBCT examination of all root filled teeth as part of primary care dental services. Additionally access to CBCT within the NHS is limited and therefore will not be used in this study. It is acknowledged that radiographic assessment is flawed but would be providing information about healing additionally to clinical findings.

2.4.4.5 Assessing Patient Related Outcomes

One of the main issues being discussed across medicine and dentistry with regard to outcome-based research is the patient perspective (Darzi, 2008). The aim is to use patient reported outcomes to develop patient centred care. So far in dentistry OHIP (Oral Health Impact Profile) has been used as a measure of patient perspective (Slade & Spencer, 1994). In other parts of medical PROMs (patient reported outcome measures) and PREMs (patient reported experience measures) are also being introduced (Department of Health, 2008). As discussed earlier, patients are likely to measure outcome in relation to the absence of symptoms (Bender *et al.,* 1996a; Bender *et al.,* 1996b), function and aesthetics (Friedman & Mor, 2004) and overall quality of life (Dugas *et al.,* 2002) although these 'measures of perceived oral health represent subjective, individual perspectives based on how the patient views personal oral health' (Atchison & Gift, 1997).

A number of questionnaires have been used to detect changes in quality of life of patients undergoing endodontic treatment or endodontic surgery (Dugas *et al.,* 2002; Tsesis *et al*., 2005; Del Fabbro *et al*., 2009; Gatten *et al*., 2011). Some have been adaptations of OHIP-14 or OHIP-49 (Dugas *et al.,* 2002; Gatten *et al.,* 2011) with a Likert scale (very often, fairly often, occasionally, hardly ever and never). Others have used variations of existing questionnaires developed for surgery (Shugars *et al.,* 1996) to evaluate post-operative patient limitations with alternative scales such as not at all, very little, some, quite a bit, very much (Tsesis *et al.,* 2005, Del Fabbro *et al.,* 2009). The latter have been used on the day of treatment and then for several days post-operatively. As surgery was not assessed in the current study, questionnaires developed from Shugars *et al.* (1996) were not used. Wording in questionnaires developed by

Dugas *et al.* (2002) and Gatten *et al.* (2011), is more appropriate for North American populations. Rasheed (2012) developed and validated an OHIP questionnaire especially for endodontics called the OHIP - Endodontic Outcome Measure (OHIP-EOM) with 16 questions modified from OHIP-49. This questionnaire was developed specifically for England, included all areas used in the North American questionnaires and was tested in London (Rasheed, 2012). It was therefore considered more appropriate to use the OHIP-EOM in the current study.

OHIP-EOM is a modification of OHIP-49. Sixteen questions across seven domains were developed. Face validity was obtained using experts (clinicians who worked in primary care) and by piloting on 30 patients (before and after endodontic treatment provided at Kings College Dental Hospital). Content validity was obtained via expert opinion and literature review. The non-response rate for each item on the questionnaire was less than one percent. A paired t-test was used to measure construct validity and a statistically significant difference was seen for all domains ($p=0.000$). Reliability was measured using Cronbach's alpha with values >0.85 for all items on the questionnaire. All items with the exception of 'trouble pronouncing any word' were correlated significantly ($P=0.01$) with global oral health rating. Multivariate regression analysis at item level showed the measure to be stable against external factors, such as age and gender. The questionnaire was concluded as valid, reliable and responsive (Rasheed, 2012). The questions are shown in Table 11 and compared to other versions of OHIP questionnaires related to endodontics (Dugas *et al.*, 2002; Gatten *et al.*, 2011; Rasheed, 2012). Differences were related to wording of individual items and a reduction in the number of questions.

Patients that have to live with chronic illnesses develop a 'response shift' whereby, they change their internal standards, values and the conceptualisation of their quality of life (QoL), therefore QoL can mean different things to different people, and different things to the same person at different time periods and according to disease trajectory (Sprangers & Schwartz, 1999). Response shift can occur in any field where self-reporting is required (Howard *et al.,* 1979). As a result, it calls into question fundamental assumptions about questionnaires and psychometric criteria such as reliability (high internal consistency), validity (cross measure correlation), and responsiveness (Schwartz, 2010). It has been suggested that response shift may have three major components: (1) a catalyst (a trigger that changes the health status such as treatment), (2) antecedents (such as sociodemographics, personality, spirituality), (3) mechanisms (behavioural and cognitive processed used to accommodate the catalyst such as coping mechanisms, reframing expectations and engaging in spiritual activity), which then leads to a response shift and change in perceived QoL (Sprangers & Schwartz, 1999). Perceived QoL is considered a multidimensional construct incorporating at least aspects of physical, psychological and social functioning (Siegrist & Junge, 1989; Cella & Tulsky, 1990; McMillen *et al.,* 1990).

It is suggested that people want to feel as good as they can about themselves, maintain a level of control or regain homeostasis, and this may not be a conscious process (Sprangers & Schwartz, 1999). It is recommended that QoL is investigated at various time points, in a large sample of varied individuals with acute and chronic disease processes, and at different time points within the disease process (Sprangers & Schwartz, 1999). In order to account for and measure response shift, in-person, semi-structured interviews and feedback using baseline data are required, although psychometric testing could ascertain some data reducing the labour intensive process of such surveys, with pairwise comparison of data at various time points with strong theoretical construct of questionnaires (Schwartz & Sprangers, 1999). In the current study, one might hypothesise that the effect of such a response shift can be as a result of adaptation to chronic tooth related pain before treatment, therefore the perceived QoL may be no different from what it would have been if there was no tooth related pain. This is described as habituation or active coping (Schwartz, 2010). As a result there may not be a significant change in perceived QoL after treatment. Acute symptoms and prompt treatment may alter perceived QoL much more before and after treatment. There is conflicting data relating to whether response shifts are a clinically significant phenomenon. However, it is recommended that a comparison/control group is used, hypotheses about when the response shift that is expected to occur are clearly stated, a combination of approaches to detect the response shift are used, and include objective clinical criterion measures to distinguish between expected and observed changes in QoL over time (Schwartz, 2010).

Table 11: OHIP-EOM (Rasheed 2012) with corresponding question number in each of the questionnaires used in this study

Study and quality of life questions for each domain			Question number in each questionnaire in this study		
Dugas *et al.,* 2002	**Gatten *et al.,* 2011**	**Rasheed 2012**	**Q1***	**Q2****	**Q3*****
Functional limitation					
Have you had trouble pronouncing words because of your teeth and mouth? Have you felt that your sense of taste has worsened because of your teeth or mouth?	Have you had trouble pronouncing any words because of problems with your teeth, mouth, or dentures? Have you felt that your sense of taste has worsened because of problems with your teeth, mouth, or dentures?	1. Have you had trouble pronouncing any words because of problems with your teeth or mouth?	11	19	3
		2. Have you felt that your sense of taste has worsened because of problems with your teeth or mouth?	12	20	4
		3. Have you had food catching in your teeth?	13	21	5
Physical pain					
Have you had painful aching in your mouth? Have you found it uncomfortable to eat any foods because of your teeth or mouth? Have you had to alter the temperature of the foods that you eat because of your teeth or mouth?	Have you had painful aching in your mouth? Have you found it uncomfortable to eat any foods because of problems with your teeth, mouth, or dentures?	4. Have you had painful aching in your mouth?	14	22	6
		5. Have you had a sore jaw?	15	23	7
		6. Have you had sensitive teeth, for example, due to hot or cold foods or drinks?	16	24	8
		7. Have you had toothache?	17	25	9
Physical disability					
Has your diet been unsatisfactory because of your teeth or mouth? Have you had to interrupt meals because of your teeth or mouth?	Has your diet been unsatisfactory because of problems with your teeth, mouth, or dentures? Have you had to interrupt meals because of problems with your teeth, mouth, or dentures?	8. Have you been unable to brush your teeth properly because of problems with your teeth or mouth?	18	26	10
		9. Have you had to avoid eating some foods because of problems with your teeth or mouth?	19	27	11
		10. Has your sleep been interrupted because of problems with your teeth or mouth?	20	28	12

Psychological discomfort					
Have you been self-conscious because of your teeth or mouth? Have you felt tense because of your teeth or mouth?	Have you been self-conscious because of your teeth, mouth, or dentures? Have you felt tense because of problems with your teeth, mouth, or dentures?	11. Have you been worried by dental problems?	21	29	13
Psychological disability					
Have you found it difficult to relax because of your teeth or mouth? Have you found it difficult to fall asleep because of your teeth or mouth? Have you ever been awakened by problems with your teeth or mouth? Have you been embarrassed because of your teeth or mouth?	Have you found it difficult to relax because of problems with your teeth, mouth, or dentures? Have you been a bit embarrassed because of problems with your teeth, mouth, or dentures?	12. Have you felt depressed because of problems with your teeth or mouth?	22	30	14
		13. Have you been a bit embarrassed because of problems with your teeth or mouth?	23	31	15
Social disability					
Have you been irritable with other people because of your teeth or mouth? Have you had difficulty doing your usual jobs because of problems with your teeth or mouth?	Have you been a bit irritable with other people because of problems with your teeth, mouth, or dentures? Have you had difficulty doing your usual jobs because of problems with your teeth, mouth or dentures?	14. Have you been less tolerant of your partner or family because of problems with your teeth or mouth?	24	32	16
Handicap					
Have you felt that life in general was less satisfying because of your teeth or mouth? Have you been totally unable to function because of your teeth or mouth?	Have you felt that life in general was less satisfying because of problems with your teeth, mouth, or dentures? Have you been totally unable to function because of problems with your teeth, mouth, or dentures?	15. Have you felt that your general health has worsened because of problems with your teeth or mouth?	25	33	17
		16. Have you been unable to work to your full capacity because of problems with your teeth or mouth?	26	34	18

*Q1 = Pre-treatment questionnaire
**Q2 = Post treatment questionnaire
***Q3 = Follow-up questionnaire

Dugas *et al.,* 2002; Gatten *et al.*, 2011, Rasheed, 2012

2.4.4.6 Assessing Healing Versus Survival

Outcomes in terms of healing (gold standard) and survival are discussed in Section 2.4.4. According to recent data (Tickle *et al.,* 2008; Lumley *et al.,* 2008), in the UK, although the quality of root canal treatment as seen radiographically can be low, tooth survival rates appear to be high. Medium to long term (median 6 years) radiographic monitoring has been shown to lead to healing in 2.4% and failure in 2.8% with the remaining 95% retaining a status quo without intervention (Van Nieuwenhuysen *et al.,* 1994). This raises the question of how important it is to measure healing, when survival maybe the adequate measure. The question follows that if tooth survival rates are not influenced by the quality of the root canal treatment, what would be the rationale for spending vast resources on training dentists and commissioning high quality root fillings?

There is evidence to suggest that current practices of endodontics are inadequate at removing all post treatment apical periodontitis and that the presence of low grade persistent infections (also defined as serious metabolic disturbances) may have some systemic effects such as activation of immune response cells in the occurrence of coronary heart disease (Frisk *et al.,* 2003; Caplan, 2004; Caplan *et al.,* 2004; Wu *et al.,* 2006). However, it has been concluded that there is a lack of high quality evidence to support the lack of systemic disorders as a result of untreated periapical disease (van der Waal *et al.,* 2015). In the presence of evidence that current practices lead to 50-90% of root filled teeth having associated apical pathology and the absence of conclusive evidence that that low grade apical infections do not cause long term systemic problems (Wu *et al.,* 2006; van der Waal *et al.,* 2015), it is important that root canal treatments are performed to the best possible standard. In medicine, there is new emphasis on 'getting it right first time' with the aim of identifying and administering the correct treatment at the appropriate time, to a high standard with minimal complications and therefore reducing the need for expensive revision treatment (Briggs, 2015). This philosophy is also applicable to endodontics.

2.4.5 Adherence to Good Practice Guidance in Endodontics amongst Dentists

It is assumed that clinical practice is a form of human behaviour and therefore it is generalised that behaviour can be modified (Eccles *et al*., 2005). Behavioural change among health care professionals has been explored to understand the barriers (Grol & Wensing, 2004; Johnson & May, 2015). Barriers to change that have been identified for a variety of tasks such as hand washing, where barriers included a lack of awareness, knowledge, reinforcement, control, social norms, leadership and facilities, or adhering to guidance on diabetes care, where barriers included models based on the individual professional, the social, organisational and economic context (Grol & Wensing 2004).

Endodontics is taught as part of the undergraduate curriculum and the use of rubber dam for isolation, sodium hypochlorite as an irrigant and electronic apex locators to establish working length are now commonplace. The European Society of Endodontology (2009) and American Association of Endodontics (2004) have published gold standards for root canal treatment since 1994 (European Association of Endodontology, 2009; American Association of Endodontics, 1994; American Association of Endodontics, 2004). Numerous studies have assessed the adherence to some of these guidelines around the world.

The survival rate of root filled teeth if rubber dam is used during treatment has been shown to be statistically significantly higher than if rubber dam was not used (Lin *et al.,* 2014), and yet, rubber dam was used by between 0.9% and 47% of dentists surveyed using questionnaires (Slaus & Bottenberg, 2002; Al-Omari, 2004; Ravanshad *et al.,* 2008; Al-Fouzan, 2010; Peciuliene *et al.,* 2010; Elham & Sedigheh, 2012; Kaptan *et al.,* 2012; Unal *et al.,* 2012; Iqbal *et al.,* 2014; Shashirekha *et al.,* 2014; Neukermans *et al.,* 2015; Raoof *et al.,* 2015; Lawson *et al.*, 2015). In Taiwan, radiographs taken during treatment were analysed to assess compliance with rubber dam use, revealing rubber dam use in 16.5% of 1,322 cases analysed. Rubber dam usage in hospital settings (33%) was 10% higher than in private practices (Lin *et al.,* 2011).

Electronic Apex Locators were being used by between 2.7% and 52% of dentists surveyed (Ravanshad *et al.,* 2008; Kaptan *et al.,* 2012; Unal *et al.,* 2012; Iqbal *et al.,* 2014; Natto, 2014; Raoof *et al.,* 2015). In the United States, the reported use of rubber dam and electronic apex locators was high, with more than 60% of respondents reporting that they always used rubber dam, and 70% reporting that they use electronic apex locators (Anabtawi *et al.,* 2013; Savani *et al.,* 2014).

Reported rated of sodium hypochlorite use for irrigation is between 33% and 95% of responding dentists (Slaus & Bottenberg, 2002; Al-Omari, 2004; Ravanshad *et al.,* 2008; Al-Fouzan, 2010; Peciuliene *et al.,* 2010; Kaptan *et al.,* 2012; Unal *et al.,* 2012; Neukermans *et al.,* 2015; Raoof *et al.,* 2015). In Germany, Australia, Belgium and Turkey, the use of Sodium Hypochlorite (NaOCl) as an irrigant was high with variation is the concentrations used and the adjunctive irrigants used depending on the teachings of their undergraduate education (Slaus & Bottenberg, 2002; Clarkson *et al.*, 2003; Kaptan *et al.,* 2012; Unal *et al.,* 2012; Neukermans *et al.,* 2015; Willershausen *et al.,* 2015).

In England and Wales, root canal treatments provided by GDPs have been assessed and only 10% of cases fulfilled the European Society of Endodontology defined technical criteria for standards of care (Dummer, 1998). Survey questionnaires of dentists revealed that 60% of dentists never used rubber dam for root canal treatment within the NHS. The reasons cited were time, remuneration, training and the view that patients may not like it. The use of rubber dam was linked to irrigant use with 70% of sodium hypochlorite users also using rubber dam. Young graduates were also more likely to use rubber dam than older graduates (Whitworth *et al.,* 2000). In Wales, less than 19% use rubber dam routinely for endodontics and almost 45% stating that they never use rubber dam, with a tendency for older dentists to use rubber dam more than younger dentists. In this survey, 89% of respondents stated that working length was established using radiographs, 19% used Sodium Hypochlorite as an irrigant, 39% used local anaesthetic as the only irrigant and 9% failed to use any irrigant at all (Jenkins *et al.,* 2001). In Northern Ireland, rubber dam was never used during root canal treatment by 39% of respondents to a survey, citing difficulty of use as a reason (Lynch & McConnell, 2007). These negative perceptions have been shown to be held also by final year dental students, more than half of whom stated they are likely to use rubber dam less in independent practice (Mala *et al.,* 2009). More recent surveys have suggested some improvement to adherences of recommendation, with 30% using rubber dam, 35% using electronic apex locators and 75% using sodium hypochlorite (Palmer *et al.,* 2009). Higher rates of the use of apex locators in root canal treatment have been reported since in the UK (Orafi & Rushton, 2013).

These findings are in keeping with other reports in healthcare that 30-40% of patients do not receive care that is in accordance with current scientific literature, in the United States and Netherlands, with 20% or more receiving treatment that is not needed or harmful (Grol & Grimshaw, 2003). The levels of compliance with recommendations were associated with the type of health problem, the quality of evidence supporting the recommendations, compatibility of the recommendations with existing values, the description of the desired performance, the complexity of the decision-making required, and the level of new skills and organisational change needed to follow the recommendations. Therefore, even if healthcare professionals are aware and willing to embrace changes in clinical practice, there is a need for environments conducive to change in order to achieve change, and change may be more difficult where complex changes in clinical practice are considered (Grol & Grimshaw 2003). It has been suggested that the use of twelve domains for behavioural change processes in implementing evidence based practice will enhance understanding behaviour change. These domains are: knowledge, skills, social/ professional role and identity, beliefs about capabilities, beliefs about consequences, motivation and goals, memory, attention and decision processes, environmental context and resources, social influences, emotion regulation, behavioural regulation, and nature of the behaviour (Michie *et al.,* 2005).

In order to achieve implementation of recommendations Grol & Grimshaw (2003) suggested interactive and continuous education, involving the discussion of evidence, peer feedback on performance and professional development. These should be built into daily patient care so that decision support tools and real-time patient-specific reminders can be used to allow healthcare workers to make the best decisions for their patients. There was recognition that the patient, the organisation, resources, leadership and the political environment may play a role in adherence to guidelines (Grol & Grimshaw, 2003).

There is emerging prominence on appraising complex interventions that are aimed at behavioural change in healthcare practitioners and failure to do this may undermine the evaluation of the intervention being tested (Craig *et al.,* 2008; Medical Research Council, 2015; Eccles *et al.,* 2009). It has been recommended that tailored interventions to change behaviour of health care practitioners is compared to non-tailored or no intervention (Baker *et al.,* 2010; Baker *et al.,* 2015). A feasibility study is required to identify the barriers to changing the clinical steps in the practice of providing root canal treatment in general dental practice (primary care), and develop and test instruments to capture real time data on the provision of care and instruments to measure outcome of root canal treatment before and after behaviour change of the dentist.

2.4.6 Complexity of Endodontic Treatment

All teeth do not have the same root canal morphology and depending on whether treatment has been provided previously, the provision of a root canal filling may post different difficulties in different teeth. Figure 4 shows a range of complexities of teeth requiring endodontic treatment.

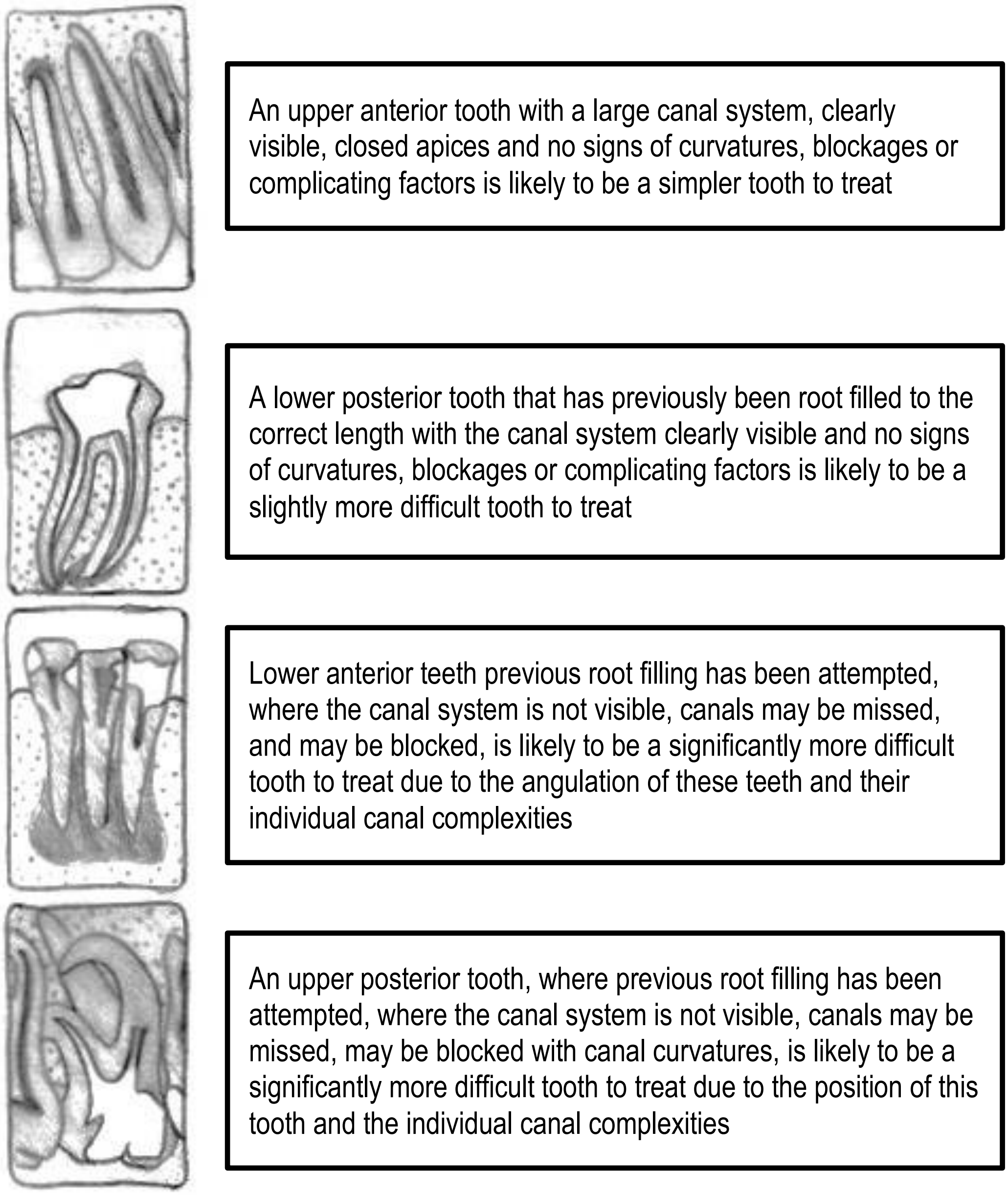

Figure 4: Pictorial presentation of potential tooth related factors that may complicate the ability to provide endodontic treatment

Muthukrishnan *et al.* (2007) evaluated a system for grading the complexity of root canal treatment in the UK. The Index of Restorative Dental Treatment Need (RIOTN) developed by Falcon *et al.* (2001) was used as the grading system, which was not markedly dissimilar to those outlines by the Royal College of Surgeons of England and the American Association of Endodontology. The non-surgical endodontic component of the RIOTN system is as follows:

- Complexity grade 1 (Low): Single/multiple root canals with curvature <15' to the root axis that are considered negotiable from radiographic or clinical evidence through their entire length. No root canal obstruction or damaged access. Incise and drainage.
- Complexity grade 2 (Moderate): Single/multiple root canals with curvature >15' and <40' to the root axis that are considered negotiable from radiographic or clinical evidence through their entire length. Teeth with incomplete root development.
- Complexity grade 3 (High): Single/multiple root canals with curvature >40'. Single/multiple root canals that are NOT considered negotiable from the radiographic or clinical evidence through their entire length. Surgical treatment. Teeth with iatrogenic damage or pathological resorption. Teeth with difficult root morphology.

There are a number of modifying factors, including patient factors such as medical history as well as endodontic re-treatment, which were considered to increase complexity by one increment (Falcon *et al.,* 2001). The RIOTN was used to assign complexity grades to 186 teeth (using clinical and radiographic findings) by the chief investigator retrospectively. Sixty randomly selected cases were then reassessed in the same way one year later by the chief investigator, a consultant in restorative dentistry and a Vocational Trainee who had been qualified for six months. Although the system was seen to be rapid and easy to use the reproducibility was moderate to poor. A variety of reasons were highlighted including ambiguity and subjectivity (Muthukrishnan *et al.,* 2007). The available tooth complexity factors are summarised in Table 12, with the tooth related factors contributing to 'moderate complexity' explained in Table 13. When the tooth is compared to this definition of moderate complexity, if at least one of the items of moderate complexity is met, the tooth is considered moderately difficult to treat and would therefore meet the criteria to be referred from a general dentist to an appropriate practitioner for treatment.

Table 12: Available definitions of complexity for teeth requiring root canal treatment (only tooth related factors included) as described in the Royal College of Surgeons of England guidelines (2001), the American Association of Endodontists guidelines 2005 (edited 2010), and the Index of Restorative Dental Treatment Need (RIOTN) (Falcon *et al.,* 2001)

Complexity	RCS England guidelines (2001)	American Association of Endodontists guidelines 2006 (edited 2010)	RIOTN (Falcon *et al.,* 2001)
Level 1 **Minimal difficulty** **Routine complexity**	• Single/Multiple root canals with curvature < 15° to root axis that are considered negotiable from radiographic or clinical evidence through their entire length. No root canal obstruction or damaged access • Incision and drainage	• Normal original crown morphology • Slight or no curvature (<10°) • Closed apex (<1 mm in diameter) • On radiograph canal(s) visible and not reduced in size • No resorption evident • Uncomplicated crown fracture of mature or immature teeth • No previous endodontic treatment • None or mild periodontal disease	• Single/multiple root canals with curvature <15' to the root axis that are considered negotiable from radiographic or clinical evidence through their entire length. No root canal obstruction or damaged access. Incise and drainage.
Level 2 **Moderate difficulty** **Moderate complexity**	• Single/multiple root canals with curvature > 15° but < 40° to root axis that are considered negotiable from radiographic or clinical evidence through their entire length. • Teeth with incomplete root development	• Full coverage restoration • Porcelain restoration original anatomy/alignment • Bridge abutment • Moderate deviation from normal tooth/root form (*e.g.*, fusion, tooth/root form (*e.g.*, taurodontism, microdens) • Teeth with extensive coronal destruction • Moderate curvature (10-30°) • Crown axis differs moderately from root axis. Apical opening 1-1.5mm in diameter • Radiographically canal(s) and chamber visible but reduced in size • Pulp stones • Minimal apical resorption • Complicated crown fracture of mature teeth • Subluxation injuries • Previous endodontic access without complications • Concurrent moderate periodontal disease	• Single/multiple root canals with curvature >15' and <40' to the root axis that are considered negotiable from radiographic or clinical evidence through their entire length. Teeth with incomplete root development.

Complexity	RCS England guidelines (2001)	American Association of Endodontists guidelines 2006 (edited 2010)	RIOTN (Falcon *et al.,* 2001)
Level 3 **High difficulty** **High complexity**	• Single/multiple root canals with curvature > 40° • Single/multiple root canals that are **NOT** considered negotiable from radiographic or clinical evidence through their entire length • Periradicular surgery • Teeth with iatrogenic damage or pathological resorption • Teeth with difficult root morphology	• Restoration does not reflect original anatomy/alignment • Significant deviation from normal tooth/root form (e.g. fusion, dens in dente) • Extreme curvature (>30°) or S-shaped curve • Mandibular premolar or anterior with 2 roots • Maxillary premolar with 3 roots • Canal divides in the middle or apical third • Very long tooth (>25 mm) • Open apex (>1.5 mm in diameter) • Radiographically – indistinct canal path or canal(s) not visible • Extensive apical resorption • Internal resorption • External resorption • Complicated crown fracture or immature teeth • Horizontal root fracture, alveolar fracture • Intrusive, extrusive or lateral luxation, avulsion • Previous endodontic access with complications (e.g. perforation, non-negotiated canal, ledge, separated instrument) • Previous surgical or nonsurgical treatment completed • Concurrent severe periodontal disease • Cracked teeth with periodontal complications • Combined endodontic/periodontic lesion • Root amputation prior to endodontic treatment	• Single/multiple root canals with curvature >40'. Single/multiple root canals that are NOT considered negotiable from the radiographic or clinical evidence through their entire length. Surgical treatment. Teeth with iatrogenic damage or pathological resorption. Teeth with difficult root morphology.
Modifying Factors relevant to Root Canal Treatment	• A modifying factor can only increase complexity by one increment. Multiple factors are not cumulative. • Endodontic retreatment		• Patient factors such as medical history and endodontic re-treatment.

Table 13: Definition of moderate difficulty developed for the Dentists with Enhanced Skills in Endodontics Course (Al-Haboubi *et al.,* 2014)

DwSI Factors	▪ DwSI will not undertake surgical endodontics ▪ DwSI will only provide root canal therapy for teeth that can secure rubber dam ▪ The DwSI has the right to refer a patient to a specialist if they feel that the referral from the GDP is above their skill level
Patient factors necessitating referral as moderately difficult	**Suitable referrals:** ▪ Well motivated patient without active caries or periodontal disease ▪ Where a GDP has experienced problems with achieving local anaesthesia ▪ Reduced access with maximal inter-incisal mandibular opening within range of 25mm to 35mm. ▪ Patient co-operation problems that include: anxiety and/or a 'gagging' susceptibility that can be controlled without sedation or GA and where the patient can tolerate rubber dam and endodontic therapy (with reassurance and encouragement from the DwSI practitioner) ▪ Medical compromise that does not require intravenous infusions of antibiotics or blood products are suitable ▪ Mild learning difficulties: where the patient can both understand and co-operate with the concepts of endodontic therapy (under local anaesthetic) are sometimes suitable for referral to the DwSI on the grounds that the treatment can be provided more efficiently and effectively. **Inappropriate referrals for the DwSIs:** ▪ Patients with active caries and periodontal disease ▪ Reduced access with maximal inter-incisal mandibular opening less than 25mm ▪ Patients with unstable angina, poorly controlled type 1 diabetes, severe breathing difficulties, evidence of major organ failure, past IV Bisphosphonates or radiotherapy to the jaws ▪ Patients that display type 1 hypersensitivity to dental products (e.g. local anaesthetic agent(s); dental cements and Latex rubber)
Tooth factors necessitating referral as moderately difficult:	**Moderately difficult Tooth Anatomy:** ▪ Root curvatures of 35 degrees and less ▪ Root canals of 25mm or more length ▪ Pulpal and coronal root canal sclerosis; with obvious radiographic evidence of patency in the mid and apical thirds of the root canal ▪ Multi-rooted teeth: where the referring GDP has attempted but experienced problems with the location, instrumentation and obturation of the root canals present ▪ Anterior teeth with large root canals and apical foramina ▪ *Anterior teeth displaying alveolar fractures, root fracture(s), internal resorption or external resorption should initially be referred to a specialist for advice.* ▪ *Developmental tooth abnormalities such as: bifid apex, complex branching of root canal(s), dens in dente, germination & C shaped canals are not suitable for DwSI referral. These teeth should be first assessed by a specialist.* **Moderately Difficult Non-Surgical Revision:**

	▪ Teeth previously treated with a root filling that is short of ideal working length and where there is evidence of likely canal patency beyond the root existing filling to allow the placement of a new root filling within 2mm of the radiographic apex ▪ Presence of an existing root filling that is likely to be dissolvable with commonly used solvents ▪ Teeth that are free of caries, restorable and not associated with major iatrogenic errors such as: apical overfill (in presence of apical pathology); perforation of root canal / pulpal floor or the presence of a difficult 'ledge' within a root canal that will prevent the placement of a new root filling within 2mm of radiographic apex ▪ Silver point revisions should only be undertaken by the DwSI if where there is evidence of full length points in situ ▪ *Revision of Thermafil root fillings and sectional silver points should be referred to a specialist* ▪ *Overfilled teeth (particularly when associated with symptoms and periapical pathology) should be referred to a specialist* **Separated Instruments:** ▪ Separated instruments that are located within the coronal half of the root canal system ▪ *Separated instruments that are contained within the apical half of the tooth should be referred to a specialist* **Existing Restorations – Moderately Difficult:** ▪ Sometimes difficult dismantling is better carried out by the DwSI - particularly if it is important for example, to preserve the coronal portion of silver points or posts. ▪ The referring GDP has the responsibility to extirpate a symptomatic pulp prior to referral; where it is possible to achieve anaesthesia and access to the pulp chamber ▪ The DwSIs will be trained to remove dentine pins, posts which will include: short (less than 8mm) tapered brass screw posts (Dentatus) and poorly-fitting (and thus leaking) short (less than 8mm) parallel posts. ▪ DwSI will be able to assess cracked teeth and advise the referring GDP and patient of the best way forward. The DwSI will be trained to place an Orthodontic stabilisation band and, if necessary and under magnification, remove the existing restoration to visualise the coronal aspect of the tooth. DwSIs will be able to root treat the tooth if it is clear that the crack / fracture does not extend to the wall(s) of the pulp chamber or into the furcation. *More extensive fractures should be referred to a specialist.* ▪ Bridge Abutments should be 'stripped-down' and investigated by the referring GDP in the first instance. The referral to the DwSI will then be based on the likely moderate difficulty of the future endodontics. ▪ *Well-fitting posts of greater than 8mm in length will be referred to a specialist.* ▪ *Long (greater than 8mm) parallel and serrated posts and posts likely to be associated with root or pulpal chamber perforation (as evidenced by intra-oral radiographs) are not suitable for DwSIs.* **Tooth Restorability:** ▪ There needs to be sound coronal tooth tissue above the alveolar crest of the toothy referred to the DwSI ▪ Deep inter-dental root caries is normally very difficult to predictably restore after the root canal therapy.

2.4.7 Measuring Training in Endodontics and Outcomes of Root Canal Treatment

In Miller's pyramid of assessment of learning, the first step of assessing knowledge and skills is the demonstration that the student 'knows', followed by demonstration of 'knows how', 'shows how' and 'does' (Miller, 1990). Therefore, the outcome of training in endodontics could be measured using the change in knowledge ('knows'), the adherence to recommended guidelines ('knows how'), development of technical skills ('shows'), adaptation of techniques/instruments/materials ('does'), and the outcome of root canal treatment ('does'). The outcome of root canal treatment could be measured using clinical and radiographic healing as well as patient related outcomes.

2.4.7.1 Objective Assessment of Knowledge

Knowledge in dentistry is measured most often using various examinations that may be written or oral (Mattheos *et al.,* 2009). Learning is related to the way students are assessed or tested on the topic (Brown *et al.,* 1997). It has been recognised that multifaceted approaches to assessment are required to gain and understanding of competence and the students ability to learn and to achieve lifelong learning, with logbooks and reflective learning gaining importance (Mattheos *et al.,* 2009; Brown 2001). Objective assessment is easier using written methods of assessment such as multiple choice questions or short answer questions testing recall where absolute correct answers are present. This becomes more difficult when essays test critical thinking and defence of evidence based opinions developed by the student (Schuwirth & van der Vleuten, 2004). Essays and oral examinations are considered appropriate for testing synthesis of information but are considered unreliable with low generalizability. Case-based scenarios with a problem-based methodology are favoured and examples of criteria for assessment have been published, with an emphasis on reflection (Mattheos *et al.,* 2009). As part of the course development, an educationalist was involved in the development of various assessment methods such as essays, short answer questions and multiple-choice questions. Due to the difficulty in using these for assessing higher order thinking and the advantages of using a case based discussion as a method of assessing reflective learning, this method of assessment was used in this pilot training initiative.

2.4.7.2 Objective Assessment of Technical Skills in Root Canal Treatment

The measurement of technical skill is very difficult and subjective. It may be possible to measure improvement in technical skill in root canal treatments by giving each participant a number of standardised canals to prepare and obturate prior to additional teaching, and then again following additional teaching. An absence of technical errors, ideal shape of prepared canal with an obturation free of voids extending to within two millimetres of the radiographic apex is a possible gold standard that is measurable by radiographic means (Peak *et al.*, 2001; Friedman, 2002; Farzaneh *et al.,* 2004; Ng *et al.,* 2007; Ng *et al.,* 2008a; Ng *et al.,* 2008b; de Chevigny *et al.,* 2008). The most difficult of these to define is the ideal shape of the canal. Proposed descriptions are 'continuous taper' (Schilder, 1974), 'conical' (Bryant *et al.,* 1998), and since the advent of rotary instruments 'remaining centred within the canal' (Kandaswamy *et al.,* 2009). The 'Schilder taper' is funnel shaped with the smallest diameter being at the canal apex and the widest diameter being at the canal orifice (Schilder, 1974).

Endodontic training blocks (clear casting resin blocks) have been used in a number of studies to assess preparation techniques in endodontics (Tharuni *et al.,* 1996; Zmener & Banegas, 1996; Coleman *et al.,* 1997; Martin *et al.,* 1997; Thompson & Dummer, 1997; Kum *et al.,* 2000; Calberson *et al.,* 2002; Yang *et al.,* 2006) because of their ability to simulate canals of a predetermined size, shape and curvature. The similarity to tooth structure has been hampered by the low Knoop hardness: 22kg/mm^2 in resin blocks compared to 40kg/mm^2 in teeth (Weine *et al.,* 1975; Khalilak *et al.,* 2008). Endodontic training blocks used in this training course had a hardness of 22kg/mm^2 with a size of ISO #15, a root taper of 0.02, a 35-degree root curvature and a mean canal length of 18 mm (REF A 0177, Dentsply Maillefer, Ballaigues, Switzerland).

There has been validation of these resin blocks for ultrasonic instrumentation of root canals (Ahmad, 1989), for studying the shape of a prepared canal (Lim & Webber 1985) and assessing apical canal transportation (Khalilak *et al.,* 2008).

Lim and Webber (1985) used resin blocks of $22kg/mm^2$ hardness and extracted teeth to compare the proportion that developed hourglass shapes during preparation. Photographs of the radiographs of the extracted teeth and the resin blocks were magnified (x10) and measured. A statistically significant difference in the incidence of hourglass shapes following preparation between the groups was not found and it was concluded that simulated root canals formed in clear casting resin (with a hardness of $20kg/mm^2$) were a valid experimental model for studying the shape of prepared root canals (Lim & Webber, 1985).

Khalilak *et al.* (2008) used high hardness resin blocks (Farahani, Tehran, Iran) with a Knoop hardness of $40kg/mm^2$, low hardness resin blocks (Endo Training-Bloc 0.02 Taper Dentsply Maillefer Ballaigues, Switzerland) with Knoop hardness of $22kg/mm^2$ and extracted molar teeth. A statistically significant difference was found in canal transportation between the extracted teeth and the low hardness blocks, the high hardness blocks and the low hardness blocks, but a statistically significant difference was not found between the extracted teeth and the high hardness blocks (Khalilak *et al.,* 2008).

The blocks have been assessed in a variety of ways, from taking photographs (Lim & Webber, 1985), scanning (Khalilak *et al.,* 2008), to using a video camera connected to a light microscope and computer with image analysis software measurements being made on superimposed pre- and post-operative digitised images of resin blocks positioned in a bespoke holder (Calbersn *et al.,* 2002).

Alternative methods for practicing technical skills in endodontics being developed include 'virtual reality', where preparation of the 'virtual tooth' is completed on a computer or 'simulator'. This is followed by the simulator measuring the quality of the preparation carried out by the student against those carried out on the simulator by experts in the field or against set quality parameters within the software. This is said to add consistency to scoring and allow objective quantitation of the quality of the preparation and therefore the technical skills demonstrated (Suebnukarn *et al.,* 2014; Al-Jewair *et al.,* 2010).

2.4.7.3 Objective Assessment of Quality of Root Canal Treatment Provided

It is important to understand 'quality' within dentistry, especially within primary care where the majority of dental treatment takes place (Campbell & Tickle, 2013a). However, 'quality' in dentistry is currently not well defined. Many facets of quality have been described within dentistry, such as professional standards and technical aspects of treatment, patient views including access, communication skills of healthcare workers and continuity of care, prioritisation of efficiency outcomes of care in terms of access and value for money (Campbell & Tickle, 2013a). The importance of measuring 'quality' in dentistry for all stakeholders including patients, clinicians, commissioners and policy makers has been recognised (Tickle & Campbell, 2013). Defining and measuring quality is the first step to quality assurance and quality improvement (Campbell & Tickle, 2013b).

Quality of endodontic treatment provided is difficult to quantify and measure objectively. Often the measurement is done using a postoperative radiograph, which gives limited information regarding the complexities involved in the treatment. Technical quality of non-surgical endodontics has been assessed by a number of groups using a variety of scoring systems (Appendix D). These scoring systems most often use the quality of the root canal filling as a measure of the quality of the root canal treatment and healing as seen radiographically as a measure of outcome. It has been suggested that measurement of quality in dentistry be multifaceted (Campbell & Tickle, 2013a) and measures be conceptually grounded, valid, reliable, acceptable to both clinicians and patients as well as be pragmatic and feasible to use (Tickle & Campbell, 2013).

In root canal treatment, three main aspects interplay in the concept of clinical quality:

- Factors relating to the clinician providing the treatment (e.g. the skill level, confidence and equipment available)
- Factors relating to the patient (e.g. medical history, anxiety, limited mouth opening and treatment tolerance)
- Factors related to the tooth being treated (e.g. the level of curvature of the canals, sclerotic dentine preventing easy location of the canal, difficulties removing existing root canal obturation materials).

It is difficult therefore to score the quality of endodontic treatment on a single postoperative radiographic film with all of the above mentioned accounted for. Certain conditions have been found to improve apical healing and this may be a potential method of measuring quality of endodontic treatment (Ng *et al.,* 2011).

The earliest scoring system was reported in 1983 (Reit & Grondahl, 1983) when the quality of the root filling was deemed adequate or defective based on radiography of 119 cases. Periapical healing was scored from 0-3 categorical by non-calibrated examiners (three specialists in endodontics and three oral radiologists). Four of the examiners repeated the scoring three months later. In relation to the quality of root filling, complete independent agreement between all examiners occurred in 32% of cases. Radiologists agreed in 52% of cases and endodontists agreed in 56% of cases. All observers independently arrived at the same periapical diagnosis in 39% of cases. Radiologists agreed in 57% of cases and endodontists in 59% of cases. Intra-examiner reliability was higher at the extreme ends of the rating scale (Reit & Grondahl, 1983). In a second part of the same study, six endodontic specialists scored the periapical status of radiographs. The opinions of all examiners only coincided in 15% (n=6) of cases (Reit & Hollender, 1983).

Ørstavik (1986) recommended a score for healing based on matching radiographs to a series of five reference radiographs that were representative of the histological changes in relation to periapical status. Examiners were asked to choose the reference radiograph which most closely resembled the periapical area being studied, when in doubt assigning a higher score and for multi-rooted teeth to assign the highest of the scores given to individual roots. Kirkevang (2000) used this and a scoring system for quality of root filling to correlate quality of root filling with periapical healing. Inadequate root canal fillings and inadequate coronal restorations were associated with apical periodontitis (clinical symptoms were not assessed). Others have carried out similar studies (Boucher, *et al*., 2002; Segura-Egea *et al*., 2004; Loftus *et al.,* 2005; Eleftheriadis & Lambrianidis, 2005; Molander *et al.,* 2007; Bierenkrant *et al.,* 2008, Frisk *et al.,* 2008, Keyahan *et al.,* 2008, Moussa-Badran *et al.,* 2008, Tavares *et al.,* 2009, Santos *et al.,* 2010, Unal *et al.,* 2011, Fonseka *et al.,* 2013).

Bierenkrant *et al.* (2008) carried out a retrospective analysis using clinical notes and radiographs. The clinical notes were used to gather information regarding tooth type, type of treatment (non-surgical primary or secondary endodontic treatment), procedural errors, apical enlargement size, number of visits, irritants and intracanal medicaments. Radiographs were scanned and saved in Joint Photographic Experts Group (JPEG) format coded for patient and operator. Three assessors scored the radiographic appearance of the root filling in relation to density of root filling in the apical, middle and coronal third of the root, the taper of the obturation, the lateral adaptation of the obturation, extrusion of material beyond the apex, number of lateral canals, apical enlargement and transportation of the canal. This analysis was based on the system developed by Molander *et al.,* in 2007.

Molander *et al.,* (2007) assessed the technical quality of two groups of 94 GDPs undertaking lecture based and hands-on training in endodontics and two examiners scored the cases before and after education. One group of dentists underwent a 4-hour lecture, one group underwent the 4-hour lecture and 6-hour hands-on training course, and the third group underwent no training. Although a decrease in the rate of low quality root fillings after education was observed, the difference was not statistically significant.

Others have used ESE guidance, PAI scores and quality of root fillings determined by Orthopantomograms (Loftus *et al.,* 2005). Van De Sluis *et al*., (2005) sectioned root filled lower anterior teeth *in vivo* and concluded that oval canals may have compromised root canal fillings allowing more fluid transport through the root fillings.

All studies in this area across numerous countries and health care settings have used similar criteria relating to root canal filling length, homogeneity of root filling, taper of obturation and the presence/absence of procedural errors. Taper has been assessed in relation to subjective assessment by two or more examiners in most studies and by way of measuring the width at the apex and at the coronal, middle and apical thirds of the canal in in-vitro studies (Schilder 1974; Molander *et al.,* 2007; Bierenkrant *et al.,* 2008; Dahlström *et al.,* 2011; Fonseka *et al.,* 2013; Dahlström *et al.,* 2015). Radiographic healing has been scored using the Periapical Index (PAI) for which examiners were trained and calibrated using 100 radiographs (Ørstavik, 1983). Multi-rooted teeth have had all of the roots scored and the most severe score carried forward to represent the tooth (tooth as the unit of analysis). Inter- and intra-examiner reliability was measured using Cohen's Kappa statistical analysis (Cohen, 1960).

The reported reliability and validity of the various scales used (Appendix D) were variable. In some studies, scales used to assess the quality of the root filling (and in some cases the quality of the coronal seal) were not reported as validated although some reported inter- and intra-examiner reliability (Reit & Hollander, 1983; Reit & Gröndahl, 1983; Van Nieuwenhuysen *et al.,* 1994; Ray & Trope, 1995; Tronstad *et al.,* 2000; Kirkevang *et al.,* 2000; Hommez *et al.,* 2002; Boucher *et al.,* 2002; Segura-Egea *et al.,* 2004; Van de Sluis *et al.,* 2005; Loftus *et al.,* 2005; Eleftheriadis & Lambrianidis, 2005; Lynch & Burke 2006; Molander *et al.,* 2007; Bierenkrant *et al.,* 2008; Frisk *et al.,* 2008; Kayahan *et al.,* 2008; Moussa-Badran *et al.,* 2008; Tavares *et al.,* 2009; Santos *et al.,* 2010; Unal *et al.,* 2011; Fonseka *et al.,* 2013; Dahlström *et al.,* 2011; Koch *et al.,* 2013; Dahlström *et al.,* 2015; Azim et al., 2016). Although there were similarities between the domains scored, there were differences between the scales and significant subjectivity (Appendix D). Therefore, none of the scoring systems were ideal to be used directly in the current study. The only study with validation of the scales as well as careful training, calibration, reliability testing was the development of the PAI scoring system for healing (Ørstavik, 1983). This scale has been used widely in one form or another; therefore, the PAI scale developed by Ørstavik (1983) was used to measure healing in the current study.

A review of the literature was carried out to ascertain if there were any studies that assessed training in endodontics, within primary care using measures for outcomes of root canal treatment, the findings of which are described in the following section.

2.5 Literature on Post-graduate Training of Dentists in Primary Care

A review of the literature was performed to identify studies where the assessment of training to improve skills in endodontics, uses the outcomes of root canal treatment, when general dental practitioners in a primary care setting provide root canal treatment before and after training. The search strategy has been defined in section 2.5.1 and the search was updated in June 2016. The inclusion criteria were: English Language or translation to English available, any setting, root canal treatment carried out in patients, and any aspect of post-graduate training in provision of root canal treatment.

2.5.1 Literature Review Strategy

The scope of the study was mapped using a mind map (Appendix E). This resulted in the development of key words related to the subject area of 'Assessment of training in endodontics within primary care using measures of outcomes of root canal treatment' (Appendix F) and used in a similar way to Medical Subject Headings (MeSH) terms used in *Medline and ClinicalTrials.gov* registry, however, in this search any words thematically related to the subject area were chosen. These searches were run on MEDLINE and EMBASE. Search findings are shown in Appendix G.

2.5.2 Literature Review Findings

The search identified 30 articles and hand searching identified a further five relevant papers. The articles retrieved from each database were merged in a word document and all titles were read to remove duplicates. Once duplicates were removed, 28 articles were assessed against the inclusion criteria. Where the abstract did not facilitate decision-making, the full paper was reviewed. There were no randomised controlled trials assessing one method of training against another using the outcome of root canal treatment as a measure for the outcome of training. Twenty-one articles were excluded because they reported undergraduate experiences, assessed participant perception of knowledge without an intervention of training, did not assess any component of root canal treatment or involved virtual reality for training. Three of the excluded articles did involve assessing change in skills, however of undergraduates. These were not included as training novices basic skills of endodontics is different from changing the practises and behaviours of qualified dentists within post-graduate education. The reasons for exclusion are shown in Figure 5.

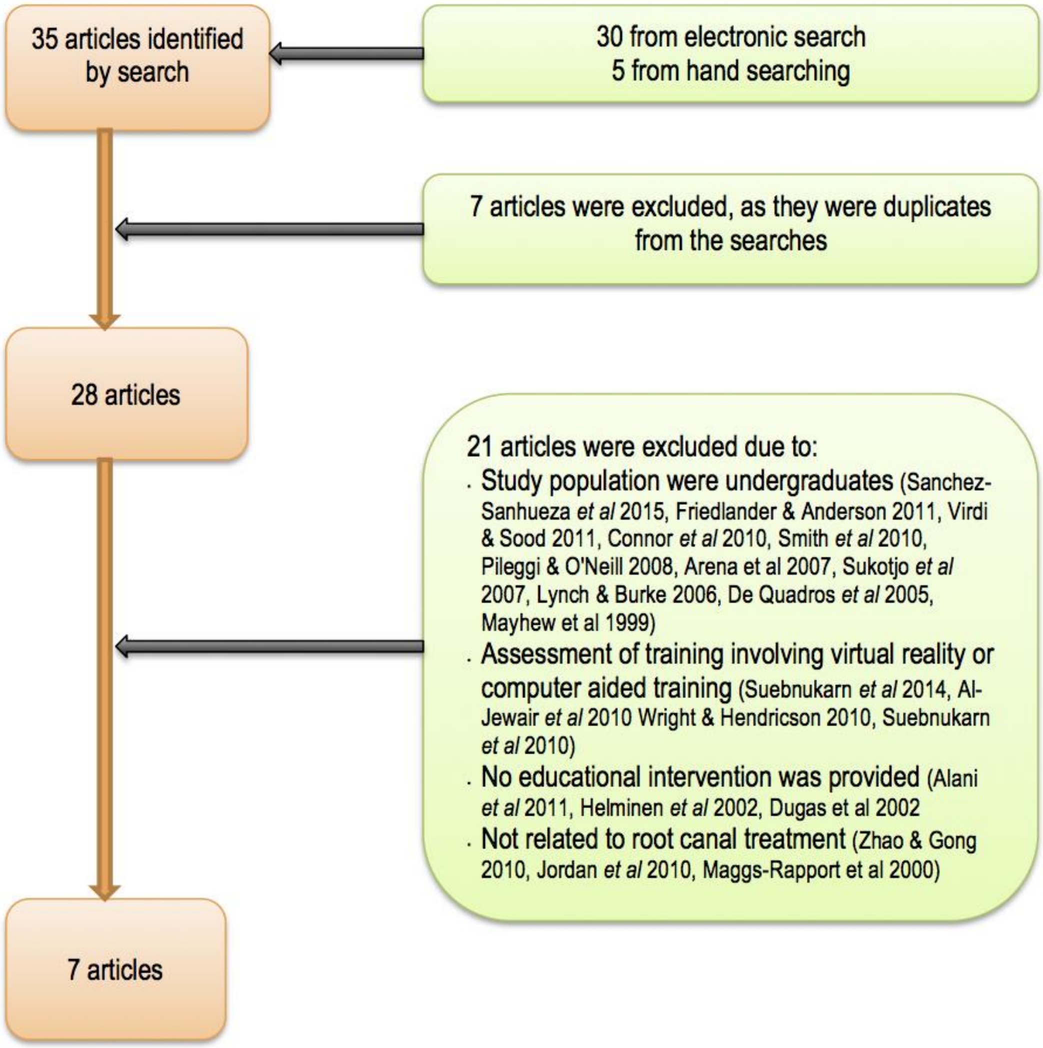

Figure 5: Reasons for exclusion of articles generated from the systematic review of the literature. (See Appendix G for full reference list generated by searches)

Seven articles reported studies on the outcomes of post-graduate education in terms of outcomes of root canal treatment: Reit *et al.,* 2007; Molander *et al.,* 2007; Koch *et al.,* 2009; Dahlström *et al.,* 2011; Koch, 2013; Koch *et al.,* 2015; and Dahlström *et al.,* 2015. All were studies carried out in Sweden, where healthcare is considered a public responsibility and this includes dental care. Sweden has three independent government levels: the national government, the county councils/regions and the municipalities. The Swedish national healthcare system is managed mainly by the county councils/regions and is responsible for ensuring that everyone living in Sweden has access to healthcare. Although there is a mixture of publically and privately owned facilities, they are in main publically funded services. Swedish law compels health service staff to work in accordance with scientific knowledge and accepted standards of practice. Dental care is subsidised and included in national health insurance, with price competition between dentists, and patients having the opportunity to pay the difference and see a more expensive dentist. Dental care is free in Sweden for those aged less than 20 years with an emphasis on prevention (Anell *et al.,* 2012).

Molander *et al*. (2007) aimed to assess the uptake of Nickel-Titanium (Ni-Ti) rotary instrumentation following various methods of education to ascertain if Ni-Ti rotary instrumentation increased the frequency of good quality root fillings as well as determine whether the format of the education influenced the quality of root fillings. This study was carried out in Gothenburg Public Dental Health Services (Sweden), and all 148 dentists employed in their 25 clinics were enrolled in the study. Ni-Ti rotary instrumentation was used by 4% of these dentists prior to the study. The endodontic equipment in each clinic was largely the same. The 25 clinics were randomised into two educational initiatives: one group received a 4-hour lecture with hand-outs, delivered by an endodontist and the other group received this lecture as well as a 6-hour practical hands-on session on simulated roots and extracted teeth, delivered by the same endodontist. The control group received no training initially and received training later on during the study. Two root-filled molar teeth were assessed from the archives for every dentist before the training, 6months after training for the experimental and control groups. The control group then went onto be randomised into lecture only and lecture and hands-on training groups and a further two root filled molar teeth were assessed 6-7months later. Radiographs were scanned and stored as JPEG images. A five level quality score was used to assess the distance of the root filling from the radiographic apex (inside canal within 2.5mm from the radiographic apex), the quality of the seal, the presence of taper and canal transportation. Analysis was simultaneous by two examiners with opportunity to adjust the brightness and contrast on the images. One year later 114 roots were reassessed to demonstrate an intra-observer Kappa score of 0.66. Paired *t*-tests were used to compare the percentage of good and poor scores pre- and post- intervention. Pre- and post-intervention radiographs were available for 94 of the 148 dentists (therefore 36% loss to follow-up). A ratio of excellent to poor root canal treatments was calculated for each group. In all groups the quality of the root fillings improved with the introduction of Ni-Ti instrumentation. Separated instruments were seen in 3.3% of teeth. No statistically significant differences were found between the different educational approaches. In this study no other aspects of root canal treatment and it was noted that radiographic film quality was not always optimal.

Reit *et al.* (2007) reported another component to the same study by Molander *et al.* (2007) using a self-reported questionnaire six months and four years following completion of training, for the same group of dentists. Short-term adoption of the new technique was higher where lecture and hands-on training was instigated; therefore, hands-on training was offered to all dentists. In both articles, participation in the study was mandatory for all employed dentists within 25 clinics. Statistical analysis performed was Pearson's Chi Squared. The number of root canal treatments being performed per week influenced the adoption rate. The behaviour of individuals appeared to influence the remainder of the dentists in the same practice and in 16 of the 23 clinics all dentists either accepted or rejected the new technique. At four years, the response rate to the questionnaires was 88%, with only 12% of these respondents reporting that they rejected the technique.

The same group investigated the quality of root fillings four years after completion of training (Dahlström *et al.* 2011). A coordinator randomly selected two root filled molars, for each dentist in October 2001 (after training, n=120) and in June 2005 (n=174). At the end of the study by Reit *et al.* (2007), all dentists were trained using lectures and hands-on training. All new dentists were offered the complete package of training with lectures and hands-on training. Again radiographs were scanned and stored as JPEGs to be analysed in the same way, using the same scoring system described by Molander *et al.* (2007). Two examiners viewed the radiographs simultaneously and where consensus was not reached, a third examiner was involved. Fifty roots were reassessed 1-month later, with intra-observer agreement reaching a Kappa score of 0.85. Statistical significance was analysed using Chi^2 with a 95% confidence interval. Cases were assessed from 88% of dentists. Substandard radiographs were excluded. The number of excellent (score 1) and adequate (score 1-3) increased from 2001 to 2005 by 7% and 8% respectively. The ratio of score 1/score 5 also increased. Separated instruments were seen in 3.5% of teeth.

Koch *et al.* (2009) used a self-completed questionnaire in two counties of Sweden, with similar endodontic provision in public dental clinics (general dental practice), to ascertain the use of Ni-Ti rotary instrumentation. The dentists employed in one county acted as a control and was exposed to the usual advertising of the technique and training provided by the Swedish Dental Association, manufacturers and the Swedish Dental Society. The dentists in the other county underwent an educational programme in endodontics conducted over two years, including a 2-hour introduction, one day seminar four times in a year, monthly presentations of guidelines and a 4-hour practical training using extracted teeth in the participants' "home clinic". The technique taught included using a stainless steel instrument and radiograph to establish working length and obturation using a single Gutta Percha point to match the preparation formed using Ni-Ti rotary instruments. One year after completion of the course, a self-completion written questionnaire was sent to all dentists in the control and intervention counties, with non-respondents receiving a reminder four weeks later. The questionnaire evaluated the following: the assessment of prognosis, the use of rubber dam, working length determination, the use of irrigation and inter-appointment dressing as well as protocols for post treatment follow-up. The instrumentation technique was evaluated to understand the adoption of the technique. The statistical analyses used were Pearson's chi-squared and Fischer Exact Tests. Of the 195 dentists working in both counties, 83% in the control and 92% in the intervention counties responded. One hundred percent of the intervention county and 94% of the control county frequently carried out endodontic treatment. Two thirds of the respondents in both counties reported that they always used rubber dam isolation for root canal treatment. There was a higher rate of adoption of Ni-Ti instrumentation in the intervention county and the treatment was completed in fewer sessions. Almost all participants in both groups established working length, used irrigation with sodium hypochlorite and used calcium hydroxide as an inter-appointment dressing.

Koch (2013) and Koch *et al.* (2015) reported on the outcome of the above-mentioned educational intervention in terms of technical quality and long-term outcome of root canal treatment. Analysis of outcomes pre-education (2002) and post-education (2005) included root filling quality (in terms of density and length), PAI score, marginal bone loss, presence and quality of the coronal restoration. A power calculation revealed that 425 teeth from each year would be required to have an 80% chance of seeing a 10% difference in the presence of apical periodontitis using the *t*-test between the two time periods. Sixty-nine dentists supplied pre-education and post-education cases. Treatment outcome was evaluated for 229 teeth pre-education and 288 teeth post-education. There was a mix of plain films and digital radiographs. Two specialists in endodontics underwent calibration and independently examined all radiographs. There was disagreement for 276 cases and a third specialist in endodontics evaluated the radiographs for a majority decision. In 72 of these cases, all three observers disagreed in 72 of the cases, reaching a final consensus after discussion. Two observers agreed on 89.6% of all observations with kappa values of 0.73 – 0.89.

Investigations by Dahlström *et al.* (2015) involved general dental practitioners in public dental services in a rural part of Gothenburg, Sweden. A local network was activated by training 25 dentists within 25 practices to act as ‘training coaches’ to further train all 90 dentists working in these practices, in the use of Ni-Ti rotary instruments as part of a mandatory continuing education programme. Each clinic elected training coaches from among themselves. A specialist trained the coaches, with training including lectures by an endodontist (4-hours) and hands-on training

(6-hours) on models (plastic blocks) and extracted teeth. The coaches had a 6-month training period before GDP education and were reunited with the endodontist before GDP education began. All of the GDPs received the lectures from the endodontist. The coaches were allowed to train in a method of their own choice but were expected to include collective hands-on training and discussions. The hypothesis was that the activation of a network would increase the adoption of Ni-Ti rotary instrumentation and in turn improve root-filling quality. The outcome of was the technical quality of the root filling as seen radiographically. Written questionnaires at two time points (pre-education and 6-months post-education) were used to determine if the Ni-Ti instruments were adopted and their satisfaction with the instruments, introducing recall and reporting bias. The quality of the root filling was assessed just before training and 6-months post-training, using two most recently filled molar teeth pre-education. Plain films were scanned and saved as JPEG images for assessment. Four aspects were assessed: apical distance (inside the canal and within 2.5mm from the radiographic apex), quality of seal in the apical two thirds, presence of taper and canal transport. Two examiners simultaneously analysed the radiographs (with manipulation of the images for brightness, contrast and magnification as required). The unit of analysis was each individual root of each tooth. No mention was made of calibration, training or inter-examiner reliability. Intra-examiner Kappa score was reported to be 0.85 when using a 5-point scale for quality. Statistical analysis was performed with Pearson's chi-squared with 95% confidence interval. Results showed 88% used Ni-Ti rotary instrumentation after education compared to 21% before education. Training did not appear to change dentists' confidence in treatment procedures. Excellence in root filling quality increased from 45% to 59% after education. However, 13% were non-adopters. A quality ratio was calculated (number achieving highest score/number achieving lowest score) and an improvement was shown post-education. Eleven dentists from nine different clinics produced 49% of the poorest quality root fillings and 73% of these dentists stated they had adopted Ni-Ti rotary instrumentation. This study did not assess the treatment process of providing root canal treatment, healing or patient related outcomes.

Other studies have used self-completed questionnaires to establish the uptake of rotary instrumentation (Barbakow & Lutz 1997, Reit *et al.,* 2007, Koch *et al.,* 2009, Thomas *et al.,* 2013). Barbakow & Lutz (1997) found 58% response from 305 dentists, 50% of whom reported using the technique taught. Reit *et al.,* (2007) found that hands-on teaching was better than lectures; achieving 94% reported use of the technique taught with hands-on training compared with 53% with lectures. Koch *et al.,* (2009) demonstrated that, after training in the use of rotary instrumentation, 89% reported using these techniques frequently or routinely. Thomas *et al.,* (2013) surveyed dentists in Wales on the use of Ni-Ti rotary instrumentation and found only 13% of primary care practitioners reported use of these instruments compared to 82% of secondary care practitioners. It has been suggested that practitioners working in isolation are slower adopters (Coleman *et al.,* 1966; Bahrani & Evans, 2001; Southgate *et al.,* 2001).

These seven articles (Reit *et al.,* 2007; Molander *et al.,* 2007; Koch *et al.,* 2009, 2013, 2015; Dahlström *et al.,* 2011, 2015) reported the findings from three studies, and all report lecture-based teaching with a hands-on component of four to six hours duration. Training was mainly in the technique of using a specific rotary instrumentation system in primary care. The studies report the adoption of the technique introduced through education, using self-reported written questionnaires, with potential for recall and reporting bias, as on-going reporting of the treatment process was not undertaken and/or clinical notes were not assessed to verify the use of the reported treatment processes. Outcome in all studies were assessed using radiographic appearance of the root filling with some elements of procedural errors and a more lenient approach to the length of the root filling compared to other studies (Appendix D). Healing as seen radiographically was assessed using the PAI scoring system (Ørstavik 1983) in accordance with convention. Although the reported use of the techniques taught increased after training, and the score for the appearance of the root filling as seen radiographically improved after training, the number of low quality root fillings did not decrease significantly and healing rates did improve change significantly.

These studies (Reit *et al.,* 2007; Molander *et al.,* 2007; Koch *et al.,* 2009, 2013, 2015; Dahlström *et al.,* 2011, 2015) have been useful exploration of measuring process and outcome in primary care. However, there is a deficiency in the literature regarding the effect of structured, long term, post-graduate training on the adoption (change in behaviour of dentists) of recommended protocols for root canal treatment (treatment process) and the outcomes of root canal treatment (appearance of the root filling as seen radiographically, healing and patient related outcomes), especially in NHS primary care in the UK. This study makes use of the opportunity presented by a pilot training programme within primary care to assess these various domains performed in primary care.

2.6 Mixed Methods Research

Traditional methods for outcome-based research have involved quantitative analysis measuring objective change. Although this indicates if there is a change and if so, the direction of the change, there is little scope for exploring the causes or reasons for the said change. Therefore a combination of quantitative research to look for a change and a qualitative analysis to understand the factors underpinning the change were used (mixed methods research) in this study.

Mixed methods research combines elements of quantitative and qualitative research approaches to gain a better understanding of the researched area. It allows for the development of methods and techniques closer to what researchers actually use in practice (Johnson & Onwuegbuzie, 2004). Most health services research requires mixed methods research because of its complexity. Quantitative research is objective where the outcomes can be measured reliably and independently verified. It is said that qualitative research attempts to ascertain in-depth understanding of behaviour and rationale behind behaviour as a pre-requisite for quantitative research (O'Cathain *et al.*, 2007). Time- and context-free generalisations are sought after in quantitative research but are neither desirable nor possible in qualitative research (Johnson & Onwuegbuzie, 2004). In some cases qualitative approaches will be more appropriate and in others quantitative approaches will be required depending on the nature of the questions under investigation. Some argue that the two methods are incompatible (Howe, 1988) and whilst others regard a mixed methods approach a 'third paradigm' (Tashakkori & Teddlie, 2003); a paradigm that is most suited to addressing complex issues, such as education and healthcare.

Mixed methods research in healthcare research is not uncommon with 18% of health services research projects being described as mixed-methods research (O'Cathain *et al.*, 2007). The reasons for carrying out mixed-methods research in this field were cited, including, comprehensiveness addressing a wider range of questions, ability to bring patient centred approaches to studies, obtaining a broader picture of a phenomenon within complex interventions such as health services, especially where policy related research was concerned (O'Cathain *et al.*, 2007). Specific to dentistry there have been recent studies in NHS Dental Contracting where quantitative findings allowed testing of hypotheses formed in qualitative analyses (Harris *et al*., 2015; Hulme *et al*., 2016). Some have used structured interviews, case study data, questionnaires with qualitative data and quantitative data, thereby using the findings to triangulate and cross check the themes in the qualitative and quantitative parts of the study (Harris *et al.*, 2015). Others have used interviews and focus groups to ascertain qualitative data such as stakeholder views, and outcome data such as bleeding on probing, percentage of sound tooth surfaces, percentage of extracted teeth, percentage of filled teeth, and oral health quality of life scores to understand cost effectiveness of services (Hulme *et al.,* 2016).

Applicability or feasibility of mixed methods research in assessing the outcome of training on root canal treatment provided by general dentists in primary care is limited. It is also important in healthcare research to not only have quantitative information about the outcome of interventions, but also have insight into the range of possible reasons for the occurrence of such outcomes (O'Cathain *et al.*, 2007). Thus, the assessment of improvement in knowledge, skill, clinical, radiographic and patient related outcomes and cost estimation used a multi-method quantitative and qualitative approach, specifically to be able to recreate the phenomena leading to good outcomes and avoid those leading to poor outcomes.

2.7 Feasibility and Pilot Studies

Pilot and Feasibility studies are used as a trial run and allow identification of whether a larger research project will fail; they identify practical and political problems that may need to be overcome to make a larger project work (van Teijlingen & Hundley, 2001). If problems arise in the pilot and feasibility studies, for example, with the measurement tools or process of research, these must be corrected prior to the full trial.

A feasibility study is defined as a small exploratory piece of research carried out before a main study in order to estimate important parameters needed to design the main study (Arain *et al.,* 2010). They need not be randomised, do not evaluate the outcome of interest and do not require a sample size calculation; however, the sample should be sufficient to estimate the critical parameters to the required degree of precision (Arain *et al.,* 2010). A pilot study is a smaller version of the main study used to understand if the components of the main study would perform as expected, and may be the first stage of the final study (Arain *et al.,* 2010). The data collected may be analysed separately (external pilot) or within the main study (internal pilot) and therefore contribute to the final analysis (Arain *et al.,* 2010). The MRC framework (2015) supports the use of feasibility and pilot testing prior to investment of resources for main trials (Medical Research Council, 2015) as shown in Figure 6.

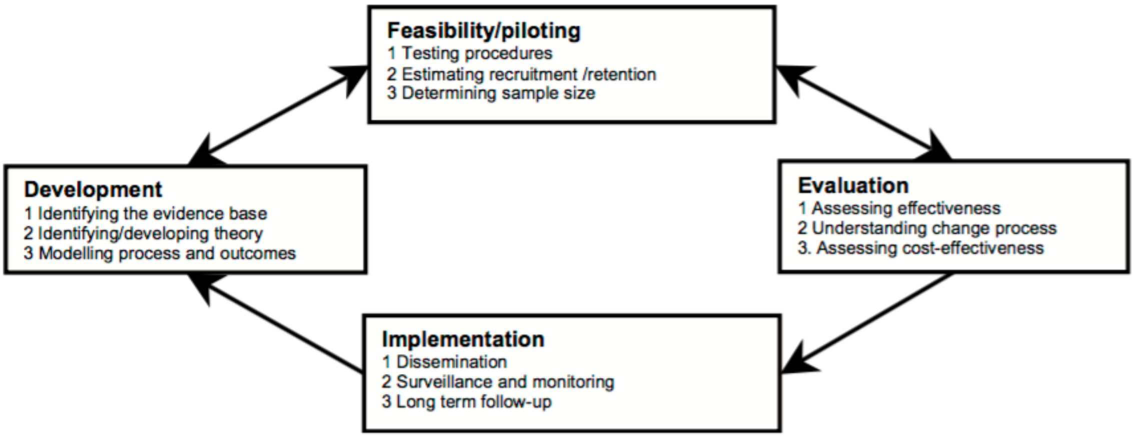

Figure 6: Key elements of the development and evaluation of a complex intervention
Medical Research Council, 2015

The Medical Research Council guidelines recommend that pilot or feasibility studies should be considered prior to major trials, for 'package interventions' such as an educational course (Arain *et al.,* 2010, Lancaster *et al.* 2010). It is not recommended that hypothesis testing be carried out, as this requires a powered sample size calculation and not all pilot studies have a control group; however the conduct and publishing of pilot and feasibility studies is encouraged irrespective of the outcome. Within pilot studies it is suggested that a sample size of 30 or more patients be used to estimate a parameter and when estimating the standard deviation, using at least an 80% upper one sided confidence limit rather than the estimate itself (Browne, 1995). It is recommended that pilot studies have well-defined aims and objectives, analysis be descriptive or focus on confidence intervals, results from hypothesis testing should be treated as preliminary / interpreted with caution and if significant differences are found, the main study should still proceed (Lancaster *et al.,* 2004).

Pilot or feasibility studies provide useful information for the design and implementation of more complex future investigations. Data from pilot/feasibility studies should mainly use descriptive statistics, without hypothesis testing (Arain *et al.* 2010, Thabane *et al.* 2010, Lancaster *et al.* 2004). Feasibility studies can also be used to establish the probable variability of the outcome measure, estimation of the sample size, willingness of participants to be randomised, clinicians to recruit participants, establish inclusion and exclusion criteria, training of staff, understand the characteristics of the proposed outcome measures or to design suitable outcome measures. They also allow establishment of follow-up rates and response rates to questionnaires (Lancaster *et al.* 2004, Arain *et al.* 2010). Feasibility studies should follow best practice for larger trials and aim to randomise, blind, have a control group if possible. However, do not need to evaluate the outcome of interest. A pilot study tests the potential components of the main study to establish that the processes (such as recruitment, randomisation, intervention, follow-up and outcome measures) will work in the 'real world' (Lancaster *et al.* 2004, Arain *et al.* 2010). Data from the pilot may contribute to the large-scale study or be kept separate as an external pilot. For research grant applications, the findings of pilot studies could be helpful in making a bid for funding (Arain *et al.* 2010).

The systematic review in this research revealed few studies assessing post-graduate training using the outcomes of root canal treatment as measures of training outcomes. None of the studies were in primary care within the UK nor did they use scoring systems reflective of current clinical practice. This suggests the need for the development and testing of measurement instruments reflective of what occurs in everyday clinical practice in endodontics, as well as evaluating the outcomes of post-graduate training using these instruments. The feasibility of achieving this in a primary care setting is unknown.

This feasibility and pilot study intends to ascertain the possibility of carrying out outcome research in primary care by developing and testing outcome measures for root canal treatment and using these to understand the change in skills of general dental practitioners exposed to post-graduate training, while working within primary care. The pilot data will inform power calculation for future studies comparing the outcome of various methods of training in endodontics.

2.8 Summary

This chapter discussed root canal treatment, current healthcare including NHS systems and the move towards improving quality, access and outcomes by ensuring the availability of an appropriately trained workforce. Importance of continuum of skills from undergraduate to generalist through to generalist and the importance of having generalists with extended skills. The available literature for the assessment of changes in skills in dentistry and the outcome of endodontic treatment were critically appraised. There was very limited evidence in the literature regarding the feasibility of providing such training, the effect of such training on the dentist's skills and the outcome of endodontics provided by Dentists with Enhanced Skills (also now being termed 'Tier 2') within primary care, especially within the UK. This study takes the 'real world' opportunity presented to capture data from this pilot initiative in order to inform future training and research to assess change in skills and outcomes of various training models for endodontics. The following chapter outlines the aims and objectives of this feasibility and pilot study which acts as the first steps towards measuring training outcomes in terms of change in skills and outcome of treatment using clinical and patient related outcome measures.

Chapter 3: Aims and Objectives

3.1 Aim

The long-term Aim of this study is to generate assessment tools for determining the impact of postgraduate training programmes for General Dental Practitioners (GDPs) in the provision of root canal treatments. In turn, it is expected that these tools will permit a quantitative assessment of the change in skill of treatment providers, before and after such training, with allowance to assess the feasibility of and understand incentives for engaging GDPs in future research on the relationship between skill improvement and outcome of root canal treatment.

3.2 Objectives

1. Development of assessment tools using expert opinion and literature, that will allow the measurement and exploration of the following outcomes at different levels:

    - Change in skills following additional training and adoption of treatment process predictors of outcome assessed at the level of the clinician
    - Radiographic and clinical outcome of treatment and patient experience assessed at the level of the patient

2. To understand the views of patients using the service and dentists who underwent the training using self-completed questionnaires
3. To estimate the cost of training to inform future planning of training linked to service provision in primary care

Chapter 4: Materials and Methods

This multifaceted feasibility and pilot study is a retrospective analysis of educational components of a training course designed to enhance root canal treatment skills of a selected group of dentists using educational assessment tools, endodontic training blocks (*in vitro*) completed as part of the course assessments, and analysis of a sample of such treated teeth at the beginning and at the end of the course (*in vivo*). The prospective component of the study involved NHS patients recruited by DES treated within London during and at the end of the programme. The quality of root canal treatment performed by DES was measured by scoring the quality of the process of providing root canal treatment, by radiographic assessment of the appearance of the root filling and healing, clinical assessment of the healing process and patient related outcomes measured using a previously developed oral health impact profile for endodontic outcome measures (OHIP-EOM). Patient perspective on the service and dentist perspectives of the course and the cost of training were also ascertained.

This chapter describes the Methods and Materials used in this study. The first section describes gaining ethical approval (Section 4.2). This is followed by the introduction of new measurement tools to be used, describing their development, rationale and testing (Section 4.3). Training and calibration are described (Section 4.4). The next section depicts the instruments used for capturing 'real world' data and their piloting (Section 4.5 and 4.6), followed by inclusion criteria (Section 4.7), informed consent (Section 4.8), randomisation and blinding (Section 4.9), data collection (Section 4.10) and data analysis (Section 4.11). Figure 7 provides an overview of the research methodology for assessing the feasibility of carrying out health services research measuring the outcome of training using clinical, radiographic and patient related outcomes.

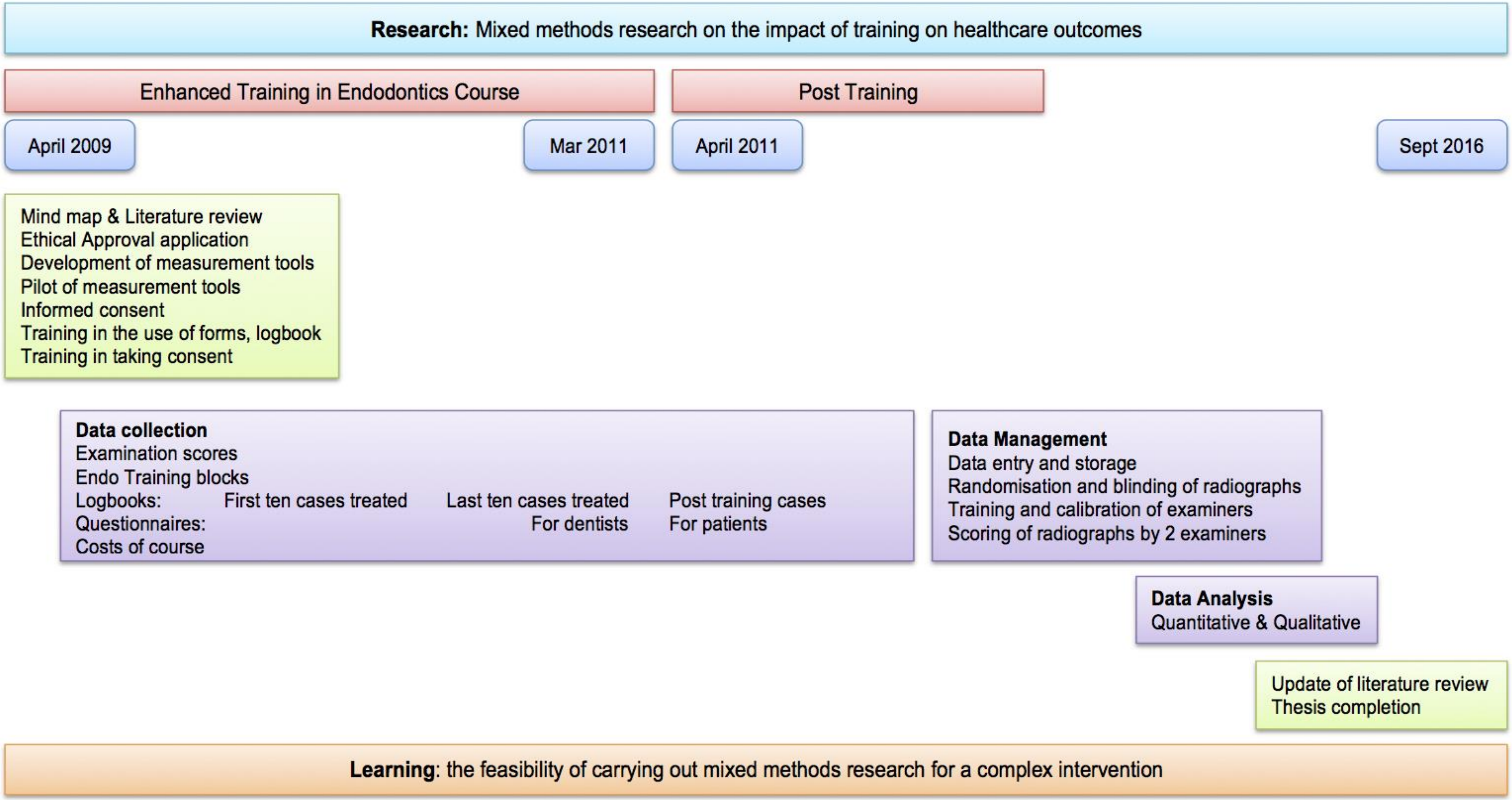

Figure 7: An overview of the research methodology for this study

4.1 Ethical and Research Governance Approval

This study received Full Committee Ethical Approval (Ref No. 10/H0718/69) (Appendix H). Research Governance approval was sought and received from all seven Primary Care Trusts who nominated dentists to take part in the training: Barking and Dagenham PCT (ref no 2298), Ealing and Hounslow PCT, Greenwich PCT (ref no RDGre573), Hammersmith and Fulham PCT, Newham PCT, Kingston PCT and Wandsworth PCT (St George's Healthcare ref no: 2010/401K, W) who had a dentist enrolled in the programme and Kings College London, reference number KCH11-006 (Appendix I). The logistics of this process was difficult and caused significant delay to some of the aspects of data collection.

Main components of the ethical issues considered and practised in this study were; anonymity of the dentists involved, confidentiality of the identity of the patients and data protection. Person identifiable electronic data were maintained on an encrypted USB device and printed/paper based data was stored in a labelled box. All research data were maintained in a secure manner at the department of the Division of Population and Patient Health at King's College London Dental Institute. All data were anonymised at the point of receipt and handled according to the Caldicott principles (Caldicott, 1997). Human tissue analysis was not a part of this study.

4.2 Informed Consent

Informed consent was obtained at two levels. The first was for the dentists who participated in the study and the second, was for the patients who received treatment as part of the study. The London Deanery provided approval for research during the course and obtained consent from dentists and patients for this. Consent for post-training research was separately obtained from all those involved.

4.2.1 Informed Consent for Taking Part in Training Initiative & Related Research

Providing informed consent for dentists and seeking it from patients to participate in research was a stipulation in the agreement to be part of the training initiative and therefore were consented for such by the London Deanery and PCT.

All Trainee Dentists enrolled in the training programme were informed of the planned study verbally and in writing. Data required for the study were collected as a mandatory part of the training course, recorded in logbooks completed and maintained by the dentists. Formal consent from the participating dentists was also obtained for involvement in the study prior to patient involvement.

All patients being treated during the course were consented for being treated as part of an educational programme and for their treatment data (anonymised radiographs and clinical records included in the logbook) being used for anonymised analysis of training outcome. These data were used for analysing change in practice (part 1 of the study). The investigators of the study were not provided with a copy of the consent forms used, although this was requested from the dentists involved.

4.2.2 Informed Consent for Taking Part in Research Post-Training

Following Ethical and Research Governance approval, participating dentists were sent an information sheet and a consent form (Appendix K and L). They were given a minimum of one week to decide whether or not to consent to this evaluation and it was made clear that they were free to withdraw at any time. They had access to the Primary and Chief Investigators to ask any questions and this ensured that they had understood the study before consenting to taking part. All trainees worked within primary dental care. Their principal dentist/service manager was also asked to provide informed consent for this study (Appendix M and N).

Post-training, when data relating to the assessment of maintaining skills and patient related feedback were to be gathered, patients attending for care during this period were invited to participate in the study by way of an information sheet and consent form (Appendices O and P). These were provided at least one week before they presented for the first treatment appointment with the DES, giving them time to decide whether or not they wished to participate in the study. The patient information sheet and consent form with details of the research project were given/sent to the patient along with their appointment by the DES. The DES were available to answer any of the patient's questions (contact details available on the information sheet). If further clarification was required, contact details were available for both the Primary Investigator (SE) and Chief Investigator (JEG). If the patient was happy to participate, they were asked to complete the written consent form on the day they present for their first treatment.

The DES participants were trained and were responsible for taking consent. Each patient was asked about his or her preferred method of follow-up contact (telephone, post or e-mail). Those willing to be contacted by e-mail were given the option of completing the follow-up questionnaire via e-mail. Any patient who declined to participate in the study was allowed to continue with treatment with the DES in the normal way and a note was made that he or she declined participation in the study to ensure further questionnaires were not sent. The refusal to participate in the research study did not affect the treatment he or she received.

4.3 Inclusion Criteria

Dentists working in general dental practices and the patients they treated were involved in this study. The inclusion criteria for these individuals to participate in the research are described below.

4.3.1 Dentists

The number of dentists participating in this study was limited to the number of dentists recruited to the course (n=9). The number of dentists being recruited was not considered important at this stage as the effect size was unknown and the pilot data from this study would inform future sample size calculations. In order to be included in the study, the dentists had to be enrolled in the Dentists with Special Interest in Endodontics course run by the London Deanery from April 2009 to March 2011, had to have completed the training course and given informed consent to participate in research. Inherently this meant that the practices they worked in had access to the required resources to provide root canal treatment. There were no other limitations placed on eligibility to participate in this research. Eight participants (4 males and 4 females) of these trainees in endodontics completed the course and therefore contributed to the analysis in this study. Participants were not being compared with another group enrolled in a full time or longer course in endodontics, but were compared with themselves at two time periods. The ninth dentist was excluded from the study as they did not complete the second year of the training as a result of not acquiring the required standard at the end of Year 1 examination, and therefore no data were available for Year 2 for this dentist.

4.3.2 Patients

One of the Aims of this study was to determine the feasibility of recruiting a representative sample of patients needing endodontic therapy. All of the patients treated by each participant dentist in the given time frame were consecutively selected. Rather than a convenience sample, random allocation of patients to treatment within the service would have been the ideal alternative, but was not possible due to logistical reasons, service arrangements and the ethical issues of those not randomised to receive treatment. As with the participating dentists, the sample size of patients was also not a priority, as the pilot data from this study would inform future sample size and this study would ascertain the feasibility of recruiting sufficient numbers (Arain *et al.,* 2010).

The included patients were all over the age of 16 (not vulnerable adults or prisoners) who underwent root canal treatment on permanent teeth. It was not known at this time that any of the dentists would be treating children only, therefore for the simplicity of the consent process; children were not included in the post-training part of the study. To achieve this sample (allowing for patients who choose not to participate), this included the entire number of patients treated towards the last two months of the course (February 2011) and up to 26 months following completion of the course (August 2013). The recruitment of patients started during the last few months of the training programme to allow opportunity for the dentists to highlight any issues with recruitment.

4.4 Coding and Tracking of Patients Treated Post-Training

As described in Section 3.1, this study was intended to determine the effectiveness of additional training for dentists in providing endodontic care as assessed by the outcome root canal treatment and patient participant satisfaction or lack of it. For this purpose, each of the patient participants had to be followed up for the entire period using a series of questionnaires. Each of the questionnaires was tracked using a patient code, which were allocated to each patient at the point of referral. This allowed patient experience to be mapped for the entire care pathway and allow clinical and radiographic outcome to be related to patient reported experience and outcome. The code included a patient identifier and DES participant identifier: each DES participant will be given an alphabetical letter ('R' to 'Y'), and each of the patients being treated by each DES participant will be given a number from one to thirty. Each DES was sent a pack containing tracking sheets, information sheets, consent forms and questionnaires. All forms contained the patient and DES participant identifier code. It was stipulated that all completed forms should be collected and posted daily or weekly to the data collection team by the patient or the practice using the envelopes provided. Alternative methods of achieving timely receipt of these could have been collection by the research team; however the latter approach may reduce perceived involvement and accountability of the dentist's team in research participation.

The training programme came to a close in March 2011. Gathering data alone was initially estimated to take a minimum of twelve months following completion of the DES course. However an extension to the data collection period (until January 2014) was required due to the difficulties of patient recruitment by DES (Appendix J shows the ethical approval extension letters). Although it would be advantageous to follow patients for up to 2-4 years to assess healing (Ng *et al*. 2011, Wu *et al.* 2009), it was not possible to gather this data in this study due to the anticipated high dropout rate of patients in this transient population in London and the long term follow-up commissioning arrangements within the service.

4.5 Data Capture Instruments

The instruments for capturing change in skills (endodontic training blocks and examination scores) were developed as part of the course, and not specifically for this study. The descriptors and scoring system for the end of year examinations were therefore simple and reliant on experience of the examiners. These instruments are shown in Figure 8 and Figure 9.

The instruments for capturing the treatment process data were also not specifically developed for this study, but for the purpose of the training course to help the participants maintain a consistent logbook whilst recording the clinically important data and clinically appropriate radiographs of the case (at the time of treatment and follow-up), more data were collected than necessary. In some instances, certain procedures were not recorded as they were assumed practice such as placement of a canal orifice seal following root canal obturation or apical gauging prior to obturation. There was also a reliance on the participants completing these records correctly and honestly. These instruments were also adopted by the dentists as a way of recording clinical practice in the patients' clinical notes and therefore were not verified against the clinical notes. Ascertaining the treatment process from the logbooks was preferred to questioning the dentists on their clinical practice as there is evidence that dentists' perception of the treatment provided exceeds the everyday practices recorded in the clinical notes (Helminen *et al.* 2002).

Treatment process – to be completed by DwSI as part of log book

General information

Participant Identification number for this study

DoB

Gender: Male ☐ 1 Female ☐ 2

Relevant medical history

Date treatment started | Date treatment completed | Number of Appointments

Initial diagnosis

Tooth notation | Number of canals

Diagnosis: Reversible pulpitis ☐ 1 Irreversible pulpitis ☐ 2
Acute apical periodontitis ☐ 3 Chronic apical periodontitis ☐ 4
Elective endodontics ☐ 5
Other:

Pre-operation status: Hx of trauma ☐ 1 Resorption ☐ 2 Fractures/cracks ☐ 3
TTP ☐ 4 Sinus ☐ 5 Swelling ☐ 6
Tenderness of sulcus ☐ 7 Mobility ☐ 8 Caries ☐ 9

Periapical status: NAD ☐ 1 Wide PDL ☐ 2 Apical lesion ☐ 3

Errors from previous Tx: N/A ☐ 1 Perforation ☐ 2 Obstruction ☐ 3
Canal morphology altered ☐ 4 Instrument separated ☐ 5

Is there any root resorption? Yes ☐ 1 No ☐ 2

Management method

Which of the following treatments were conducted? (Please tick as many as necessary)

De Novo Endodontic Treatment ☐ 1 Non-Surgical Endodontic Revision ☐ 2
Separated Instrument Removal ☐ 3 Separated Instrument Bypass ☐ 4
Post Removal ☐ 5 Surgical Endo Treatment ☐ 6
Other ☐ 7 Please specify:

Anaesthesia

Local anaesthetic: Lignocaine ☐ 1 Articane ☐ 2
Citanest ☐ 3 Prilocaine ☐ 4

Was any sedation used? No ☐ 2 Yes ☐ 1 Please specify:

Treatment details

Quality of coronal restoration: Satisfactory ☐ 1 Unsatisfactory ☐ 2

Was rubber dam used? Yes,with clamp ☐ 1 Yes, with widgets ☐ 2 No ☐ 3

State of pulp at extirpation: Vital ☐ 1 Partially vital ☐ 2 Non-vital ☐ 3

Type of irrigant used (if any): NaOCl ☐ 1 0.2%CHX ☐ 2 2%CHX ☐ 3
Iodine ☐ 4 LA ☐ 5 Saline ☐ 6 EDTA ☐ 7
Citric acid ☐ 8 Other ☐ 9 Specify

Type of lubricant used (if any): Hibi-scrub ☐ 1 Glyde ☐ 2 Other ☐ 3

Type of medicament used (if any): Ledermix ☐ 1 Ultracal ☐ 2
Ca(OH) 2 powder/H2O ☐ 3 Hypocal ☐ 4 Other ☐ 5
Specify

Was ultrasonic tip used? Yes ☐ 1 No ☐ 2 Energizer/ activator ☐ 3

Was an apex locator used? Yes ☐ 1 No ☐ 2

Canal	Ref Point	Apex Locator Zero	Working Length	Patency	Prepared Size	Apical Gauge

Method of preparation: Hand ☐ 1 Pro-Taper ☐ 2 ProFile ☐ 3
Hybrid (ProFile + Pro-Taper) ☐ 4 Other ☐ 5 Specify

Size of apical preparation: ISO 30 or smaller ☐ 1 ISO 35 + ☐ 2

Was patency filing done? Yes ☐ 1 Size of file No ☐ 2

Type of root filling material: GP ☐ 1 MTA ☐ 2 Other ☐ 3
Specify

Type of sealer: Zinc Oxide based ☐ 1 Ca(OH)2 based ☐ 2 Resin based ☐ 3 GIC based ☐ 4
Other ☐ 5 Specify

Method of obturation: Cold lat cond ☐ 1 Warm vertical/ backfill ☐ 2
Hybrid (cold lat condensation & coronal backfill) ☐ 3 MTA ☐ 4

Type of provisional restoration (if any): IRM ☐ 1 Comp ☐ 2 Temp Cr ☐ 3 Temp Post Cr ☐ 4
GIC ☐ 5 Cavit ☐ 6 Kalzinol ☐ 7 Hybrid – Cavit and Kalzinol ☐ 8
Other ☐ 9 Specify

Was cotton wool placed under restoration? Yes ☐ 1 No ☐ 2

Type of definitive restoration (if any): GIC ☐ 1 Composite ☐ 2 Amalgam ☐ 3
Crown ☐ 3 Post crown ☐ 4 Other ☐ 5 Specify

Radiographs taken: Pre-op ☐ 1 WL ☐ 2 MC ☐ 3
Post-op ☐ 4 Extra ☐ 5 Total number

Immediate assessment of Post-op radiograph (if taken): RF too short ☐ 1 RF too long ☐ 2 Voids ☐ 3
Perforated ☐ 4 Other failures ☐ 5 Acceptable ☐ 6

Any other comments:
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………

Figure 8: Form used to record the cases treated during the course

Form for patient follow-up assessment at 12 months post completion of treatment – to be completed by DwSI as part of logbook

General information	Date:		Participant Identification number for this study	

Gender: Male ☐ 1 Female ☐ 2

Follow up clinical outcomes

Patient focussed:	Asymptomatic	☐ 1	Symptomatic	☐ 2		
Clinical assessment:	NAD	☐ 1	TTP	☐ 2	Sinus	☐ 3
	Mobility	☐ 4	Swelling	☐ 5	Tenderness of sulcus	☐ 6
	Caries	☐ 7	Other	☐ 8		
	Please specify:					
Quality of coronal restoration:	Satisfactory	☐ 1	Unsatisfactory	☐ 2		

Follow up radiographic assessment:	Review period (months since Tx)	

Is extruded material still present:	Yes	☐ 1	No	☐ 2	N/A	☐ 3
Root resorption:	No	☐ 1	Yes possibly	☐ 2	Yes definitely	☐ 3
Apical radiolucency:	Yes	☐ 1	No	☐ 2		
Apical radiolucency size:	Reduced	☐ 1	Same size	☐ 2	Increased	☐ 3
	Other (specify)					
Any other negative sign:	No	☐ 1	Yes	☐ 2		
			Specify:			

Any other comments:

....

....

Figure 9: Form used to record the outcome of treatment at follow-up appointment

The marking scheme for the examinations used broad descriptors as well as comparison to the criteria of moderate difficulty (Table 14). Validated forms were unavailable for this particular course and therefore were developed as part of the course (Figure 10). Ideally the CbD marking sheets and descriptors should have been standardised for the first and second year assessments, however as these were being developed during the course, there was evolution of both as the course progressed. The CbD assessments were observed and evaluated by an educationalist from the London Deanery.

Table 14: Marking scheme and broad descriptors used for academic scoring

1	**Very poor (fail)**	No knowledge of endodontics No understanding of endodontics No reflective practice or evidence of deep learning
2	**Poor (fail)**	Very little knowledge of endodontics Very little understanding of endodontics Very little reflective practice and evidence of deep learning
3	**Below pass (fail)**	Limited knowledge of endodontics Limited understanding of endodontics Limited reflective practice and evidence of deep learning
4	**Average pass (pass)**	Basic knowledge of endodontics Basic understanding of endodontics Basic reflective practice when prompted, little evidence of deep learning
5	**Good pass (pass):**	Clear knowledge of endodontics Clear understanding of endodontics Clear reflective practice and evidence of deep learning
6	**Excellent pass (pass):**	Excellent knowledge of endodontics Excellent understanding of endodontics Excellent reflective practice, engagement in deep learning & discussion

Dentists with a Special Interest in Endodontics Pilot Training Programme
CBD Evaluation

Trainee: ……………………………………..…………………. End of Training Year: 1 2

Please grade the following areas using the scale 1- 6	Below expectations for DwSI completion		Borderline for DwSI completion	Meets expectations for DwSI completion	Above expectations for DwSI completion		Unable to comment (U/C)
	1	2	3	4	5	6	
1 Medical record keeping							
2 Clinical assessment							
3 Investigations and referrals							
4 Treatment							
5 Follow-up and future planning							
6 Professionalism							
7. Overall clinical judgement							
8. Overall knowledge of endodontics							
*U/C Please mark this if you have not observed the behaviour and therefore feel unable to comment.							
Anything especially good?			Suggestions for development				

Comments:

Your name …………………………………………… Your position…………………………………….

Your signature: ……………………………………… Date: ……………………………………….…….

Figure 10: Case based Discussion (CbD) assessment form for Year 1 and 2 examinations

4.6 Development of Quality Assessment Instruments

This study required and therefore provided the opportunity for development of research instruments to quantify current practices within the assessment and provision of root canal treatment. Measurement is the allocation of numbers an observation or theoretical concept (as in healthcare). The instruments used to make the measurement need to have defined indices, which allow the theoretical concept to be allocated numbers that reflect the presence, absence or importance of the concept. The quality of the measuring instrument is indicated by the reliability and validity of the measures (Kimberlin & Winterstein, 2008). The development of measures involves concept development, specifying the dimensions of the concept, selection of indicators and the formation of an index using literature and expert opinion. Using more than one indicator gives stability to the scores and increases the validity; the indicators are then combined to form an index (Kothari, 2004). Measurements should be against best practice as determined by the best available knowledge and technology at the time and not ideals unachievable with current knowledge and technology. Quality of care can be classified under ‘structure’ (facilities, equipment, resources both human and financial, methods of reimbursement), ‘process’ (what is actually done including the patient seeking care) and ‘outcome’ (effects of care on health status including the patient’s satisfaction with care). Good structure is expected to increase the likelihood of good process, and, in turn, increase the likelihood of good outcomes (Donabedian, 1966; 1980; 1988,).

Standards in endodontics have been defined in the European Society of Endodontology Quality Guidelines (2006) and are described in section 2.5.5 (Table 4). Trainees were already providing the clinical care associated with this evaluation. Much of the clinical data for this project were already being collected as part of the mandatory training arrangements and was contained in the logbooks maintained by the trainees during the course. The assessment of the preparation and obturation of a root canal system can be achieved using standardised endodontic training blocks and by assessment of teeth treated. This can be carried out at different time points in training to ascertain any difference in quality of treatment. This may indicate an improvement in technical skill and an overall understanding of the process of treatment to gain outcome goals. The non-clinical element is assessment of 'endodontic training blocks', which have been completed at key stages of the project in the dental laboratory as part of the mandatory training – this simulates root canal treatment in terms of technical skills but does not use human tissue. Figure 11 shows the aspects of root canal treatment that will be measured in this study.

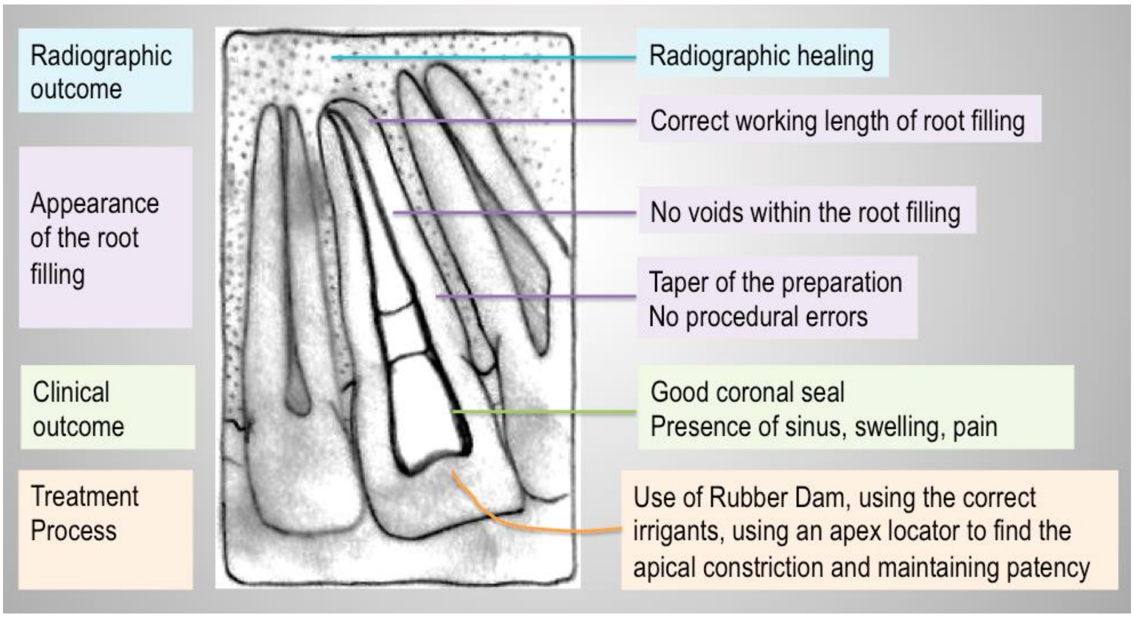

Figure 11: The factors affecting outcome of root canal treatment

In order to assess the outcomes of training, instruments that can be used to measure the outcome of root canal treatment following training were required. During this study, scoring systems for four domains of quality were developed: quality of clinical treatment process (process); quality of root canal filling as seen radiographically (process); healing as seen clinically (outcome) and healing as seen radiographically (outcome), as well as complexity of teeth treated (structure). The evidence for each aspect of root canal treatment that were measured in this study are described in the following sections, illustrating the development of the measurement tools. *In vitro*, the quality of the preparation of an endodontic training block was assessed. *In vivo*, the quality of the clinical treatment process, the quality of the root canal filling as it appears on the post-operative radiograph, healing as seen clinically and healing as seen radiographically was assessed. Clear guidance exists for the quality for quality of root canal treatment, consolidated into that shown in Table 15.

Table 15: Definition of quality in root canal treatment

	High quality	Poor quality
Clinical Treatment Process	Use of rubber dam	Not using rubber dam
	Use of correct irrigants (mainly NaOCl and EDTA)	Using LA or saline as irrigant (i.e. not using NaOCl)
	Pre-op, Mastercone & post-op radiographs of good diagnostic quality taken	Pre-op, Mastercone & post-op radiographs not taken or of poor diagnostic quality
		Perforation – not repaired or not possible to repair
	Use of apex locator to establish working length	Apex locator not used to establish working length
	Achieving patency during treatment	Patency not attempted during treatment
	Cotton wool placed in canal openings only inter-appointment	Cotton wool placed in access cavity after completion of treatment
	Interim dressing of 3mm +	Lack of interim restoration
Outcome of Obturation	Obturation within 2mm of radiographic apex	Obturation more than 2mm of radiographic apex or extruded beyond apex
	Obturation free of voids	Obturation has numerous large voids
	No perforations	
	Good seal with provisional restoration	Leaking provisional restoration
	Good seal with definitive restoration	Leaking definitive restoration
	Cotton wool not placed under definitive restoration	Cotton wool placed under definitive restoration

European Society of Endodontology guidance 2006

4.6.1 Quality Assessment Tool for Endodontic Training Blocks (*in vitro*)

In order to assess the quality of preparation of the root canal in an endodontic training block, the aspects of root canal fillings that have previously been assessed in the literature were adopted

(Friedman, 2002; Ng *et al.,* 2007; Ng *et al.,* 2008a; Ng *et al.,* 2008b; de Chevigny *et al.,* 2008a; de Chevigny *et al.,* 2008b; Farzaneh *et al.,* 2004; Souza, 2006). The initial scoring system for endodontic training blocks is shown in Table 16, where those aspects of the preparation thought to be important by experts were scored and weighted. This was then modified to be more objective as well as simplify scoring and analysis. The final scoring system for the assessment of endodontic training blocks is shown in Table 17.

Table 16: Initially proposed scoring system for assessing endodontic training blocks

Good (5 points)		Satisfactory (1 to -2 points)	Poor (-2 to -5 points)	
Points awarded for:				**Points deducted for:**
Correct WL (within 2mm of apex)	**+2**		**-2**	Incorrect WL (too short/extruded)
No procedural errors	**+2**	Procedural errors corrected	**-2**	Procedural errors
Centred within the canal - good taper and shape (maintain curvature, continuously tapering shape appropriate for size of root)	**+1**		**-1**	Over tapered or under tapered

Friedman 2002, Ng *et al.,* 2007, Ng *et al.,* 2008a, Ng *et al.,* 2008b, de Chevigny *et al.,* 2008a, de Chevigny *et al.,* 2008b Farzaneh *et al.,* 2004

Table 17: Final measurement tool used in this study for assessing endodontic training blocks

Endodontic training block Code	Procedural errors* (Y=0, N=1)	WL within 2mm of apex (Y=1, N=0)	Continuous taper and shape^ (Y=1, N=0)	Total (0=poor, 3=good)

*Ledge formation, perforations, strip perforations, canal transportation, zips/hourglass shapes, elbows, canal blockages, separated instruments and foreign objects (Hülsmann *et al.,* 2005).
^Continuous taper and shape: from the apex to the access cavity with the cross sectional diameter of the canal being narrower at every point apically, the root canal treatment following the shape of the original canal (Schilder, 1974).

4.6.2 Quality Assessment Tool for Clinical Treatment Process (*in vivo*)

Measurement of the clinical quality of the root canal treatment (clinical treatment process) was based on the goals of mechanical root canal preparations as described by Hülsmann *et al.* (2005)

and informed by other publications assessing prognostic factors in the outcome of root canal fillings (Friednman, 2002; Ng *et al.,* 2007; Ng *et al.,* 2008a; Ng *et al.,* 2008b; de Chevigny *et al.,* 2008a; Farzaneh *et al.,* 2004; Kandaswamy *et al.,* 2009; Ng *et al.,* 2011a; Ng *et al.,* 2011b). The intra operative factors considered important from the literature (Ng *et al.,* 2011a; European Society of Endodontology 2006) and expert opinion were used to develop the scoring system for the quality of the clinical treatment process. The initial scoring system for clinical treatment process is shown in Table 18, where those aspects of the preparation thought to be important by experts were scored and weighted. This was then modified to be more objective as well as simplify scoring and analysis to arrive at the final scoring system for clinical treatment process (Table 19). Data for the clinical treatment process were ascertained from logbooks maintained (compulsory record electronically or on paper) by the clinician (Section 1.3), following training on good clinical record keeping. There was complete trust in the dentists supplying accurate information, and no attempt was made to verify data in the logbooks with the patient's clinical notes.

Table 18: Initially proposed scoring system for the assessment of clinical treatment process

Good (7-8 points – rubber dam must be used)		Satisfactory (4 to 6 points)	Poor (3 points or less)	
Points awarded for:				**Points deducted for:**
Use of rubber dam	**+1**		**-1**	Not using rubber dam
Use of correct irrigants		All that does not fulfil good or poor criteria as long as rubber dam is used	**-2**	Using LA or saline as irrigant (i.e. not using NaOCl)
NaOCl	**+1**			
EDTA	**+1**			
Patency gained (file size <20)	**+1**		**-1**	Patency not gained
Apex locator used	**+1**		**-1**	Apex locator not used
Pre-op, Mastercone & post-op radiographs of good diagnostic quality taken	**+3**		**-3**	Pre-op, Mastercone & post-op radiographs not taken or of poor diagnostic quality

Friednman, 2002; Ng *et al.,* 2007; Ng *et al.,* 2008a; Ng *et al.,* 2008b; de Chevigny *et al.,* 2008; Farzaneh *et al.,* 2004; Kandaswamy *et al.,* 2009; Ng *et al.,* 2011a; Ng *et al.,* 2011b; European Society of Endodontology, 2006; Souza, 2006

Table 19: Final measurement tool used in this study for assessing clinical treatment process

Code	Rubber Dam used (Y=1, N=0)	Irrigants (NaOCl + EDTA = 2, NaOCl=1, Anything else=0)	AL used (Y=1, N=0)	Patency filing (Y=1, N=0)	Total (0=poor, 5=good)

4.6.3 Quality Assessment Tool Radiographic Appearance of Root Filling (*in vivo*)

The instrument for measuring the radiographic quality of the root canal treatment allocates a score for the quality of the root canal filling as seen radiographically. Many publications have described the use of various measures for the radiographic appearance of the completed root canal filling (Appendix D). An absence of technical errors, ideal tapered shape of prepared canal with an obturation free of voids extending to within two millimetres of the radiographic apex is the gold standard that has been used (Friedman, 2002; Farzaneh *et al.,* 2004; Ng *et al.,* 2007; Ng *et al.,* 2008a; Ng *et al.,* 2008b; de Chevigny *et al.,* 2008a; de Chevigny *et al.,* 2008b). The available literature was used to develop the current scoring systems and expert opinion was used to develop a list of factors that were thought to denote radiographic quality of obturation in root canal treatments. It was noted that the variability of an ideal tapered shape of a canal might assume less significance in the future with more widespread use of rotary instrumentation. Existing scoring systems were not used, as they were considered complicated and variable without clear reasons for using one scoring system over another. Once again the initial scoring system for the appearance of the root canal filling as seen radiographically (Table 20) weighted aspects of the obturation thought to be important by experts. This was then modified to be more objective as well as simplify scoring and analysis to arrive at the final scoring system for clinical treatment process (Table 21).

The quality of the radiograph was assessed using the National Radiation Protection Board (2001) guidelines, where score 1 was considered excellent, score 0 was diagnostically acceptable and a score of -1 was unacceptable (Department of Health/National Radiation Protection Board, 2001). Those radiographs of unacceptable quality (-1) were considered unusable and excluded from further assessment.

Table 20: Initial scoring system proposed for scoring the quality of root filling as seen radiographically

Good (5 points) (Definite 'yes' to all statements)		Satisfactory (2 to 4 points) (Questionable to all statements)	Poor (1 point or less) (Definite 'no' to all statements)	
Points awarded for:				**Points deducted for:**
Obturation within 2mm of radiographic apex	**+1**	Sealer extruded	**-1**	Obturation more than 2mm from radiographic apex or extruded beyond apex (obvious GP)
Obturation free of voids	**+1**		**-1**	Obturation has many voids
No procedural errors	**+1**		**-1**	Procedural error (s) present
Preparation centred within canal (maintaining curvature, continuously tapering shape appropriate for size of root	**+1**		**-1**	Over tapered or under tapered
Orifice seal present (2-3mm of IRM or GIC or amalgam Nayaar core)	**+1**		**-1**	Lack of orifice seal

Friedman, 2002; Farzaneh *et al.,* 2004; Ng *et al.,* 2007; Ng *et al.,* 2008a; Ng *et al.,* 2008b; de Chevigny *et al.,* 2008a; de Chevigny *et al.,* 2008b

Table 21: Final measurement tool used in this study for assessing the appearance of the root canal filling (obturation) as seen radiographically

Code	Quality of post-operative radiograph	Procedural errors* (Y=0, N=1)	Within 2mm of rad apex inside the root canal (Y=1, N=0)	Continuous taper and shape^ (Y=1, N=0)	Voids (Y=0, N=1)	Total (0=poor, 4=good)

*Missed canals, access cavity perforations, ledge formation, perforations, strip perforations, canal transportation, zips/hourglass shapes, elbows, radiographically obvious canal blockages, separated instruments and foreign objects (Hülsmannn *et al.,* 2005).

^Continuous taper and shape: from the apex to the access cavity with the cross sectional diameter of the canal being narrower at every point apically, the root canal treatment following the shape of the original canal (Schilder, 1974).

Coronal seal was not included in this analysis as a process measure, since the dentists providing the root canal treatment were not routinely responsible for the definitive coronal seal, as this was the responsibility of the referring dentist within the terms of the contract and referral systems established for this scheme (Section 1.3).

4.6.4 Quality Assessment Tool for Evidence of Radiographic Healing (*in vivo*)

Healing as seen radiographically has been used by many (Appendix D) mainly based on the work of Ørstavik *et al.* in 1986. Using this Periapical Index and a similar approach to Ng *et al.* (2011a) a scoring system was developed with weighting (Table 22) and then simplified to three possible outcomes: healed, no change and failed (Table 23).

Table 22: Initial scoring system for healing as seen radiographically

<table>
<tr><td colspan="2">Healed
(5 points)
(Definite 'yes' to all statements)</td><td>Healing
(1 to -2 points)
(Questionable for all statements)</td><td colspan="2">Failed
(-2 to -5 points)
(Definite 'no' to all statements)</td></tr>
<tr><td>Points awarded for:</td><td></td><td></td><td></td><td>Points deducted for:</td></tr>
<tr><td>Apical radiolucency did not develop after root treatment</td><td>+2</td><td rowspan="3">No change (+1)</td><td>-2</td><td>Apical radiolucency developed after root treatment</td></tr>
<tr><td>Apical area reduced in size</td><td>+2</td><td>-2</td><td>Apical area increased in size</td></tr>
<tr><td>No root resorption</td><td>+1</td><td>-1</td><td>Root resorption</td></tr>
</table>

Ørstavik *et al.*, 1986; Ng *et al.,* 2011a

Table 23: Final measurement tool used in this study for assessing the quality of outcome as measured by healing as seen radiographically

Code	Quality of follow-up radiograph	12 month Healing as seen radiographically (Reduced or no development of an apical area =2, no change in size of existing apical area =1, Increased or development of an apical area =0)

4.6.5 Quality Assessment Tool for Evidence of Clinical Healing (*in vivo*)

Clinical healing has been described as the lack of pain, swelling, sinus tracts, tenderness to palpation and percussion, tenderness in function and mobility (Friedman, 2002; Cohen & Hargreaves, 2006), therefore the presence of symptoms, clinical signs and any other negative signs were used to develop a score for healing as seen clinically at follow-up (Table 24). These details were part of that recorded, following training on clinical record keeping, in the mandatory logbook maintained by the participants in line with course requirements. An additional measure was the presence of a satisfactory coronal seal (which in this particular study may not have been placed by the dentist providing the root canal treatment therefore is included in the follow-up measurement). This should ideally be included as a process measure of the quality of the treatment process and measured clinically as well as radiographically as there is difficulty in assessment of the quality of the coronal seal (Abbott, 2004).

Table 24: Final measurement tool used in this study for assessing healing as seen clinically

Code	Symptoms Y=0, N=1	Clinical signs^ Y=0, N=1	Any other negative signs* Y=0, N=1	Total (0=poor, 4=good)	Satisfactory coronal restoration Y=1, N=0

^Clinical signs of infection such as swelling, sinus, tenderness to palpation/percussion, isolated deep pocket, mobility
*Any other negative sign such as extraction, fracture and loss of function

Friedman, 2002; Cohen & Hargreaves, 2006

4.6.6 Quality Assessment Tool for the Complexity of Teeth Treated (*in vivo*)

In order to measure the complexity of a tooth in relation to the ease with which root canal treatment could be provided, expert opinion was used to develop a list of characteristics of a tooth that may indicate complexity and compared with the tooth complexity indices from the American Association of Endodontists, The Royal College of Surgeons of England and Falcon *et al.*, Canadian Academy of Endodontics, The Dutch Endodontic Treatment Index and the Endodontic Treatment Classification (Royal College of Surgeons of England, 2001; American Association of Endodontists, 2005 edited 2010; Falcon *et al.,* 2001; Canadian Academy of Endodontics, 1998; Ree *et al.,* 2003). These were amalgamated to arrive at the tooth-related factors for radiographic assessment of complexity. Particular weighting was not given to the domains of resorption or canal obliteration to maintain a dichotomous simple measurement instrument to mirror what is done in most triaging systems and consultation appointments in the NHS to make decisions on complexity. Therefore the resultant score may be an underestimate of complexity. The assessment of the overall complexity including patient factors is beyond the scope of the current study. However, it is noted that verification of validity of this instrument is difficult and may not necessarily reflect the true complexity in a meaningful manner, as patient factors will play a role that cannot be assessed from radiographs alone. The scoring system developed used data supplied from the clinician regarding length and number of root canals (logbook) as well as data from the examiners having scored the pre-operative radiograph (Table 25).

Table 25: Final measurement tool developed for assessing the complexity of the teeth treated

Code	No of roots (One = 1 Two = 2 Tree = 3 Four = 4 Five+ = 5	Position in mouth (Up Ant = 1 Low Pos = 2 Low Ant = 3 Up Pos = 4)	Type of Tx Denovo = 1 ReTx = 2 Post removal = 3 Open apex = 4 Pre-op procedural error = 5	Resorption (Y=1, N=0)	Root curvature >35' (Y=1, N=0)	Root length >25mm (Y=1, N=0)	Canal not visible in any part of canal (Y=1, N=0)	Total (3=simple, 18=complex)

Royal College of Surgeons of England, 2001; American Association of Endodontists, 2005 edited 2010; Falcon *et al.,* 2001; Canadian Academy of Endodontics, 1998; Ree *et al.,* 2003

4.6.7 Summary of Quality Assessment Tools

This section has illustrated the evidence base behind the formalisation of everyday measurement tools for the measuring of the quality of root canal treatment. The measurement instruments were developed using expert opinion and current literature (Eliyas *et al*., 2016). The scoring system for use *in vivo* (Table 26) proved easy to use, and can be used as part of routine data collection to objectively measure of quality and outcome. The aim was to use a system as closely related to current clinical practice as possible and assess its reliability, which is described in the next section. The measurement tools developed within this study are based on the available literature and supported by other studies. Table 27 shows the literature informing the scoring systems developed. The lack of clinical signs and symptoms as well as a lack of development of periapical radiolucency post root canal treatment, or the reduction in size of periapical radiolucency post root canal treatment, will be assumed as healed or healing. The following section describes the piloting, training, calibration and reliability of these research instruments.

Table 26: Summative quality assessment tool for root canal treatment

Process	Quality of the clinical process of providing root canal treatment	Rubber Dam used (Y=1, N=0)
		Irrigants (NaOCl + EDTA = 2, NaOCl=1, Anything else=0)
		AL used (Y=1, N=0)
		Patency filing (Y=1, N=0)
Process	Quality of the root filling as seen radiographically	Procedural errors (Y=0, N=1)
		Within 2mm of rad apex inside the root canal (Y=1, N=0)
		Continuous taper and shape (Y=1, N=0)
		Voids (Y=0, N=1)
	Quality of coronal seal	Satisfactory coronal restoration (Y=1, N=0)
Outcome	Healing as seen radiographically	Apical area (Reduced or no development of an apical area =2, no change in size of existing apical area =1, Increased or development of an apical area =0)
Outcome	Healing as seen clinically	Symptoms (Y=0, N=1)
		Clinical signs (Y=0, N=1)
		Any other negative signs (Y=0, N=1)
		Total (0=poor, 15=good)

Table 27: Literature informing the quality assessment for root canal treatment used in this study

Scoring System in this study		Gold standard	Supporting Literature	Similar scoring cited in other studies	Measurement instrument
Endodontic training blocks (Examiner assessed, randomised and blinded to clinician and stage of training)	Procedural errors Yes=0, No=1	No procedural errors	Lim & Webber 1985 Khalilak *et al.,* 2008 *See below*		Table 17
	Correct Working Length Yes=1, No=0	Within 2mm of apex			
	Continuous Taper & Shape Yes=1, No=0	Continuous taper			
Clinical treatment process (Recorded by clinician, blinded to what is being assessed)	Rubber Dam used Yes=1, No=0	Rubber dam is used	European Society of Endodontology Guidelines, 2006 Lin *et al.,* 2014	Koch, 2009	Table 19
	Irrigants NaOCl + EDTA = 2 NaOCl=1 Anything else=0	NaOCl with penultimate wash with EDTA and final wash with NaOCl	Ng *et al.,* 2011a – 0.2% CHX reduces odds of success by 53%. EDTA has no effect on primary RCT but increases odds of success in secondary RCT by 2x	Koch, 2009	
	AL used Yes=1, No=0	Use apex locator to determine apical terminus	European Society of Endodontology Guidelines, 2006 Real *et al.,* 2011 - accuracy of finding apical terminus with apex locators 92% vs. digital radiographs 65% Silveira *et al.,* 2011 - accuracy of finding apical terminus with apex locators 82-92%		
	Patency filing Yes=1, No=0	Gain and maintain patency during treatment	Ng *et al.,* 2011a – if patency gained 2x as likely to have success Souza, 2006		

Scoring System in this study		Gold standard	Supporting Literature	Similar scoring cited in other studies	Measurement instrument
Quality of root filling as seen on a radiograph (Examiner assessed, randomised and blinded to clinician and stage of training)	Procedural errors Yes=0, No=1	No procedural errors	Ng *et al.,* 2011a – pre-op perforation reduces success by 56% Marquis, 2006 – healing better if no intra-operative complications de Chevigny *et al.,* 2008a – mid treatment complications reduce rate of healing by 15% in primary RCT de Chevigny *et al.,* 2008b – pre-operative perforation reduces Farzaneh *et al.,* 2004 – pre-operative perforation reduces outcome by OR of 27 in secondary RCT	Eleftheriadis & Lambrianidis, 2005; Dahlström *et al.,* 2011, 2015	Table 21
	Within 2mm of rad apex Yes=1, No=0	Obturation must be in the canal within 2mm of the radiographic apex	European Society of Endodontology Guidelines, 2006 Peak *et al.,* 2001 better outcomes if root filling <2mm from apex Farzaneh *et al.,* 2004 – root filling 0-2mm from radiographic apex better than long root filling especially if pre-operative apical area Ng *et al.,* 2008a – For primary RCT: root filling length affects outcome especially if an apical area already exists. Flush root filling > short root filling > long root filling, if no apical area. Lowest success rate if apical area + short or long Ng *et al.,* 2008b – For secondary RCT: short root filling > flush root filling > long root filling (worse if apical area also present Ng *et al.,* 2011a – Odds of success reduced by 12% for every 1 mm short of the radiographic apex. Odds of success reduced by 62% if the root filling was long	Ray & Trope, 1995; Hommez *et al.*, 2002; Boucher *et al.,* 2002; Van der Sluis *et al.,* 2005; Loftus *et al.*, 2005; Eleftheriadis & Lambrianidis, 2005; Bierenkrant *et al.,* 2008; Moussa-Badran *et al.,* 2008; Tavares *et al.*, 2009; Unal *et al.*, 2011; Fonseka *et al.,* 2013; Dahlström *et al.*, 2011, 2015; Koch *et al.,* 2015	
	Continuous taper and shape Yes=1, No=0	From apex to access cavity, cross sectional diameter of canal must be narrower at every point, root canal filling following shape of original canal	European Society of Endodontology Guidelines, 2006 Schilder, 1974	Bierenkrant *et al.,* 2008 Santos *et al.,* 2010 Fonseka *et al.,* 2013 Dahlström *et al.,* 2011, 2015	
	Voids Yes=0, No=1	No voids in the obturation	European Society of Endodontology Guidelines, 2006	Ray & Trope, 1995; Hommez *et al.*, 2002; Boucher *et al.,* 2002; Van der Sluis *et al.,* 2005; Loftus *et al.*, 2005; Eleftheriadis & Lambrianidis, 2005; Bierenkrant *et al.,* 2008; Moussa-Badran *et al.,* 2008; Tavares *et al.*, 2009; Santos 2010; Unal *et al.*, 2011; Fonseka *et al.,* 2013; Dahlström *et al.*, 2011, 2015; Koch *et al.,* 2015;	

Scoring System in this study		Gold standard	Supporting Literature	Similar scoring cited in other studies	Measurement instrument
Healing as seen on a radiograph (Examiner assessed, randomised and blinded to clinician)	Reduced or no development of an apical area = 2 No change in size of existing apical area = 1 Increased or development of an apical area = 0	Reduction or no development of an apical area	European Society of Endodontology Guidelines, 2006 Ørstavik, 1986	Reit & Grondahl, 1983; Reit & Hollender, 1983; Ørstavik, 1986; Ray & Trope, 1995; Boucher *et al.*, 2002; Loftus *et al.*, 2005; Frisk *et al.*, 2008; Kayahan *et al.*, 2008; Tavares *et al.*, 2009; Koch *et al.*, 2015	Table 23
Healing as seen clinically (Recorded by clinician at follow-up, blinded to what is being assessed)	Symptoms Yes=0, No=1 Clinical signs Yes=0, No=1 Any other negative signs Yes=0, No=1	Elimination of all clinical signs and symptoms of infection	Friedman, 2002 Cohen & Hargreaves, 2006	Ng *et al.*, 2011a Azim *et al.*, 2016	Table 24
Coronal Seal as seen clinically (Recorded by clinician at follow-up, blinded to what is being assessed)	Satisfactory coronal restoration Yes=1, No=0	Provision of a satisfactory coronal seal	Ng *et al.*, 2011a; Ng *et al.*, 2008a; Ng *et al.*, 2008b; Farzaneh *et al.*, 2004; Tickle *et al.*, 2008; Salehrabi *et al.*, 2004; Aquilino & Caplan, 2002	Ray & Trope 1995, Tronstad *et al.*, 2000; Kirkevang *et al.*, 2000; Hommez *et al.*, 2002; Boucher *et al.*, 2002; Segura-Egea *et al.*, 2004; Tavares *et al.*, 2009, Koch *et al.*, 2015	Table 24

4.7 Piloting of Data Collection and Quality Assessment Tools

Speciality Trainees piloted these instruments for data collecting in secondary care and the dentists within the course piloted the instruments at the start of the course. Feedback was used to make changes to arrive at the final versions shown in figures 8 and 9. The scoring systems were piloted among ten dentists including experts, general dental practitioners and specialist trainees. The initial scoring system was judged to be overly complicated and subjective. Therefore, the scoring systems were dichotomised, where possible to arrive at the scoring systems in Tables 17, 19, 21, 23 and 24.

Existing complexity scores were discussed and used to try and score radiographs for complexity. This revealed objective scoring often did not truly reflect the 'gut feeling' of an expert who could appreciate the intricacies. High scores were often achieved on seemingly 'simple' teeth and low scores were achieved where opinion was 'good result on a difficult tooth'. The phrase 'no two teeth are the same' is a good example of why such scoring systems are difficult to implement. An amalgamation of these could arrive at those tooth related factors for radiographic assessment of complexity, however verification of validity of this tool is difficult and still may not necessarily reflect the true complexity in a meaningful manner as patient factors will play a role that cannot be assessed from radiographs alone. The assessment using existing complexity guidelines for endodontics does not lend itself easily to objective assessment and the use of this tool may further complicate the radiographic analysis. Therefore, it was more appropriate to consider the use of dichotomous simplified criteria, with Cohen's Kappa Coefficients (Cohen, 1960) for intra- and inter-examiner variability and accept that there will be a level of subjectivity when assessing the cases. The assessment of the true complexity including patient factors is beyond the scope of the current study and therefore was not part of the domains used in developing the scoring system shown in Table 25.

4.8 Training, Calibration and Reliability of Research Tools

All of the dentists who participated in the training course were trained in the use of the data capture instruments for recording the treatment process of providing root canal treatment. This was as part of the training in order to facilitate easy recording of vital information for clinical record keeping. Secondarily, this formed the basis of the logbooks used for logging activity, reflective learning and case based discussions, which formed end of year examinations. Thirdly, these records were used within this research. The dentists also underwent training in taking consent in order to be able to recruit patients to the second part of this study. All consent forms and questionnaires were also piloted by the dentists in their own practice setting, using some of their own patients (13 patients) and the feedback was used to modify the forms.

Training of two examiners (SE and IRH) involved discussion of the scoring system for all measures using radiographs; however this initial training did not involve the scoring of radiographs. Following this, forty teeth were scored independently by both examiners, using radiographs for complexity, radiographic appearance of the root filling and healing as seen radiographically. Kappa scoring was carried out. This revealed low Kappa scores as shown in Table 31. Therefore, further training was carried out by way of both examiners simultaneously viewing the previously scored radiographs, and discussing the reasons for decision-making in each case where there were differences in scoring. Then a further thirty teeth were scored independently by both examiners and Kappa scoring carried out again. This improved the scores. Yet again, the cases scored differently were discussed as before (Figure 12). Discussion of cases using radiographs generated a list of notes for the examiners that was used for the actual scoring (Table 28). Using this learning, each examiner scored the actual cases for this research project independently. Three months following this each examiner scored 10% of the radiographs for complexity, radiographic outcome of obturation and healing. Training of the examiners to score endodontic training blocks involved discussion of the scoring system and did not involve scoring of endodontic training blocks as part of the training.

All radiographs were randomised (computer-generated tables) to blind the examiners from the clinical treatment process, the clinician and the stage of training of the DES. The examiners were also blinded to the complexity score when assessing the quality of root canal filling as seen radiographically, and blinded to the quality of the root canal filling as seen radiographically when scoring healing.

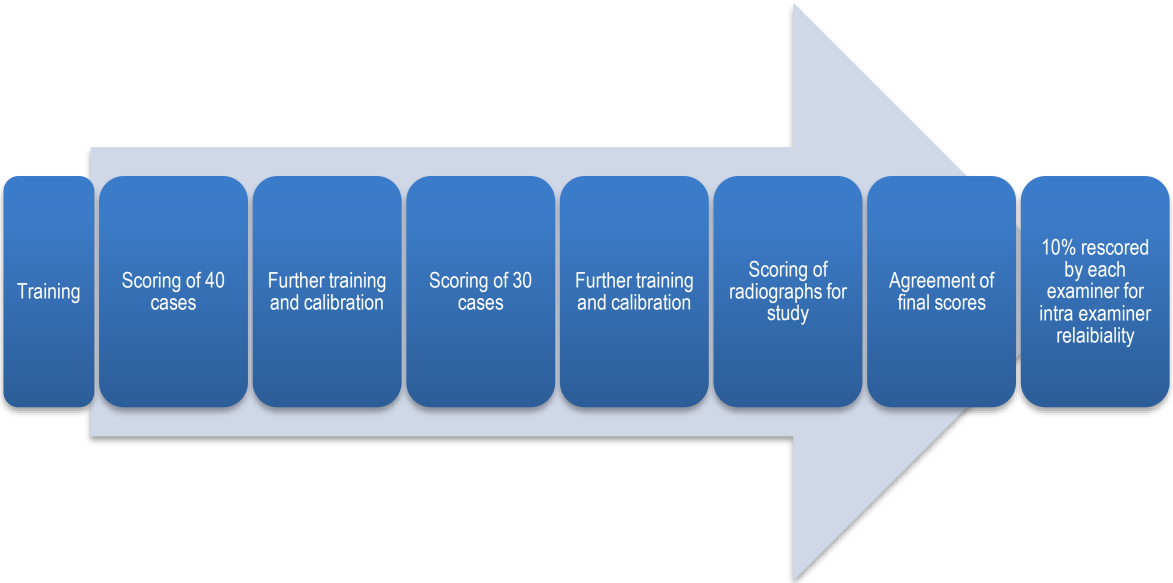

Figure 12: The number of cases scored at each stage of training, calibration and actual scoring

Table 28: Learning and agreed list of notes generated from each training and calibration sessions for scoring using radiographs

Notes for assessors (6.6.14 – post-training)	**Additional notes for assessors (15.8.14 & 18.8.14 – post calibration):**	**Additional notes for assessors (7.11.14 – post calibration):**
• Procedural errors – DO NOT include extrusion as an over preparation of the apex in this as extrusion may be due to over preparation or failure to apically gauge • Accept sealer puffs • Please score the obturation and the healing before scoring the complexity. If possible, score obturations first and then the healing. Then after 1 week I scored the complexity. • Better to score the rads on paper to reduce the light emitted from doing this on screen	• Quality of radiograph – strictly apply criteria • Score quality of obturation using POST operative radiographs • Score complexity using PRE operative radiographs (do not use post op if pre op is missing) • Score either Pre-op AND review OR post op AND review for healing • If radiograph unavailable score 'null' or leave blank • If a radiograph is present force a score – you must give a score (if in doubt give the lower score) • If coronal of the tooth to be scored is not on the film = 0 (not perfect but diagnosis possible for endodontics) • If whole root of tooth to be scored is not on the film (e.g. root tip therefore affecting ability to score) = -1 • If you score -1 for a quality of a radiograph then automatically it becomes impossible to score therefore should be entered 'null' or leave blank • If a radiograph appears blurred but all of the questions can be answered the quality of radiograph becomes 0 • 'Sclerosis' – replaced with 'Sclerosed i.e. canal not patent in any part of the root' – canal obliteration • All roots must show clear signs of continuous taper – common denominator is the lowest score • If procedural error is due to attempting instrument removal still score as procedural error as we would expect operator to stop before causing further procedural errors (but a comment can be entered in the comments column) • Continuous taper should be scores Y=1 in cases where it would be unreasonable to expect continuous taper e.g. where posts have been removed and open apices • Any tooth that has been accessed should be considered 'ReTx' for the type of treatment in complexity score table • If tooth has been apicected cannot comment on resorption therefore score 'n=0' • If apicected can only expect to fill to the root end filling (even if this appears more than 2mm from radiographic apex) • Coronal voids are part of the coronal restoration and should not be included in the 'voids' section • If scar tissue present beyond the PDL of the root, score only the PDL of root as the scar is unlikely to resolve • **If in doubt apply lowest score**	• Radiographs: For a top score should have a 5mm window/zone diameter around the apex of the tooth is question for healing scores (this is not necessary for quality of obturation). Score 0 if clinical crown is missed on the radiograph (for score of 1 will need entire tooth to be on film) • Procedural errors – include significant over extrusion as procedural error. Procedural errors relate to preparation errors rather than errors in obturation • 'Within 2mm of radiographic appearance' means within the canal therefore less than 2mm short of the radiographic apex. Any extruded GP will be scored as not within 2mm of radiographic apex • It is accepted that there will be subjective differences in scoring and therefore after all scoring is completed, discuss differences and agree a score for cases where disagreements are present

All data for inter- and intra-examiner reliability were initially entered into an Excel (Microsoft Office 2010, Microsoft, Redmond, WA, USA) spread sheet, verified and analysed using SPSS (IBM Corporation, Armonk, NY, USA) v22. The intra-examiner agreement and Kappa scores for each stage of training and calibration as well as for the actual cases scores for this study are shown in Table 29. The scores for the cases used for part 1 and part 2 have been analysed separately and can be seen in Appendix Q.

Table 29: Comparison of intra examiner reliability for assessment of radiographs and endodontic training blocks

Intra examiner reliability		Endodontic Training Blocks (N=24)				All cases (N= 24 teeth for obturation, N= 21 teeth for complexity and N=3 teeth for healing)			
		Examiner 1		Examiner 2		Examiner 1		Examiner 2	
		K	%	K	%	K	%	K	%
Obturation	Procedural errors	0.92	99	1	100	0.51	87	0.33	88
	Working length	0.81	91	0.87	94	0.82	91	0.05	63
	Continuous taper	1	100	1	100	0.6	83	0.07	54
	Voids					0.72	87	0.74	88
Complexity	Resorption					0.38	79	0.35	84
	Root curvature					0.22	75	0.5	84
	Sclerosis					0.58	80	0.87	94
	Position					1	100	1	100
	Type of tx					0.91	95	1	100
Healing						*	100	*	100

* Not able to be calculated due to the lack of significantly different scores

When the scores of the 10% of radiographs used to measure intra examiner reliability were compared to the final agreed scores for each case for agreement the Kappa scores generated were as shown in Table 30. The agreement with the final agreed score (T final) improved from the first time of scoring (T1) to the second scoring when 10% were rescored (T2).

Table 30: Intra-examiner reliability of examiners when compared with agreed final score for all cases

Intra Examiner Reliability		T1 vs. T2				T1 vs. T final				T2 vs. T final			
		Examiner 1		Examiner 2		Examiner 1		Examiner 2		Examiner 1		Examiner 2	
		K	%	K	%	K	%	K	%	K	%	K	%
Obturation	Procedural errors	0.51	87	0.33	88	0.51	88	0.50	87	0.86	96	0.25	83
	Working length	0.82	91	0.05	63	0.82	91	0.26	70	0.82	91	0.35	70
	Continuous taper	0.60	83	0.07	54	0.6	83	0.65	83	0.82	91	0.20	61
	Voids	0.72	87	0.74	88	0.82	91	1	100	0.91	96	0.82	91
Complexity	Resorption	0.38	79	0.35	84	0.6	90	0.46	90	0.69	90	0.83	95
	Root curvature	0.22	75	0.50	84	0.27	80	1	100	0.88	95	0.50	95
	Sclerosis	0.58	80	0.87	94	0.55	80	0.73	89	1	100	0.82	95
	Position	1	100	1	100	1	100	1	100	1	100	1	100
	Type of tx	0.91	95	1	100	0.83	91	0.91	95	0.91	95	0.89	95

The inter-examiner agreement and Kappa scores are shown in Table 31. The scores were initially low, but improved with further training, although it was not maintained. This was more notable for Examiner 1, who was less experienced in clinical dentistry compared to Examiner 2. The scores for the cases used for part 1 and part 2 have been analysed separately and can be seen in Appendix R.

Table 31: Inter-examiner reliability for all cases

Inter-examiner reliability		**After training (N=40 teeth)**		**After further training + calibration (N=30 teeth)**		**All cases for study (N=240 teeth)**		**Endodontic Training Blocks (N=24)**	
		Kappa	%	Kappa	%	Kappa	%	Kappa	%
Obturation	Procedural errors	0.56	84	0.44	86	0.37	85	0.83	94
	Working length	0.37	68	0.31	68	0.29	71	0.45	72
	Continuous taper	0.35	72	0.66	86	0.38	70	0.83	94
	Voids	0.44	74	0.13	79	0.54	78		
						Cases for study (215 cases)			
Complexity	Resorption	0.39	85	0.57	83	0.26	86		
	Root curvature	0	95	-0.05	83	0.18	87		
	Sclerosis	0.54	78	0.65	83	0.59	79		
	Position	1	100	1	100	0.99	99		
	Type of tx	0.83	89	0.64	78	0.85	91		
						Cases for study (32 cases)			
Healing		0.19	72	0.51	81	0.35	75		

The Kappa scores for intra-examiner reliability between 0.22 and 1, whilst inter-examiner reliability ranged between 0.18 and 0.99. The measurement tools using radiographic examination are reliable, provided that the raters have in-depth training and calibration in the use of the tool. The following section describes the methodology behind the various parts of this study.

4.9 Randomisation and Blinding of Outcome Assessors

4.9.1 Randomisation and Blinding of Dentists Collecting Data

Logbook data (including radiographs) were randomised and blinded during assessment and analysis. This ensured anonymity of the dentists and patients, as well as reducing examiner bias during scoring of the radiographs. All data were coded after collection. The codes were entered into a spread sheet for data entry. Into this spread sheet the treatment process data and data for healing as seen clinically were entered directly from the dentists' logbooks. A separate spread sheet was compiled with only the coding present for the examiners to enter scoring data for aspects scored using radiographs.

Bias introduced by patients knowing they were part of the study was a possibility. Allocation concealment was not possible, as the patients were not randomly chosen for each dentist. The selection of patients was through internal and external referral on the whole (Al-Haboubi *et al.,* 2014) and there may have been some bias with patients being referred by the dentists within the training programme. In order to reduce selection bias by the dentists and researcher, the referral process could be made completely external with randomisation and allocation concealment. Potential DES and patients treated during course were aware from the outset that they would be evaluated but unaware of which aspects of the recorded data from their logbooks were being used for research. Bias introduced by dentist knowing that they were to be assessed was overcome by not informing the dentists of the aspects of treatment that would be scored as part of quality. It was recommended that all cases treated during the course formed the logbook to eliminate reporting bias. There was reliance on the dentists adhering to recommended record keeping recommendations. In order to prevent bias in future studies, all data could be collected as part of electronic contemporaneous record keeping (General Dental Council, 1997; 2005; Steele, 2009; NHS Commissioning Board, 2013; McDonald *et al.,* 2010).

4.9.2 Randomisation and Blinding of Examiners Scoring Radiographs

Primary Investigator (SE) collected, randomised and blinded data approximately 3 months prior to scoring radiographs. Bias introduced by assessors knowing which were pre- and which post-treatment was overcome by the operator and stage of training being randomised and blinded to all examiners during scoring. Randomisation was carried out using computer-generated tables (Excel™, Microsoft Office 2010, Microsoft, Redmond, WA, USA). Ten percent of the radiographs were randomised and re-scored independently by both examiners approximately 3 months after initially scoring. All examiners were also blinded to the course participant, the stage of training, the treatment process and the patient related outcomes when assessing the root filling as seen radiographically, healing as seen radiographically and scoring complexity of the cases.

4.10 Data Collection and Scoring of Radiographs

4.10.1 Academic Knowledge Score from Course Assessments

Academic knowledge was ascertained from the training course assessments. As part of the course a number of assessments, formative and summative, were carried out. Each course participant was assessed at the end of each session with regard to knowledge and practical skill through observation during the seminars and practical sessions, where possible, by two course tutors. These assessments did not form part of the overall assessment of change in skills due to the fact that a number and variety of teachers were involved in the assessments and some teachers did not complete formal assessment forms. These did not form part of the academic score in this study.

At the end of Year 1 and then again at the end of Year 2 (end of course), participant dentists were assessed in a 30minute viva voce examination. The examination at the end of Year 1 involved each participant compiling two written cases (one short and one long) of their choice from the cases treated during that year. The short case aimed at highlighting one particular aspect of treatment deemed of importance to the participant (often a new skill learned or difficult aspect of treatment overcome with the training gained). The long case included a comprehensively documented case with all aspects of treatment detailed. Encouragement was given to reflective practice and support with current evidence. These were treated like Case based Discussions (CbD) however, with a formative component and a summative component. The examining panel comprised of at least one internal and one external examiner. The examination at the end of the course (Year 2) was similar in format but with discussion of one single long case. The validity of this examination was assessed by an educationalist.

The examination panel included three internal examiners and one external examiner, both of whom remained constant in both the examination panels used at the end of Year 1 and Year 2. Therefore, the scores of these two examiners were analysed in this study. The resultant score from these examinations comprised the component of this study relating to change in knowledge, ethics and attitude (academic score). CbD scores making up the end of Year 1 and Year 2 assessment were collected and entered into an Excel (Microsoft Office 2010, Microsoft, Redmond, WA, USA) spread sheet and proofed. Performance at the end of Year 1 was compared to that at the end of Year 2.

4.10.2 Quality of Performance on Endodontic Training Blocks (*in vitro*)

Assessment of preparation of a canal in an endodontic training block was used to evaluate the technical skills of the dentists enrolled, at the beginning and end of the course. The endodontic training blocks were routinely completed and collected as part of the regular course evaluation. These were technical laboratory tasks, which simulate some aspects of clinical care, but are completely separate from clinical care and did not involve human tissue. The participants spent the assessment day preparing an endodontic training block in the clinical skills laboratory before and after their CbD examination. The endodontic training blocks were then collected at the end of the day and assessed in relation to technical skill. One or more endodontic training blocks were also completed on day one of the course to gain an understanding of the standard of technical skill before the course teaching began. The dentists were allowed to use any of the instrumentation techniques that they were comfortable with. A record of which technique was used was not collected. Speed of preparation was not assessed. The blocks were randomised and one endodontic training block for each participant was randomly selected taken forward for scoring as per Table 17 and analysed. Inter- and intra-examiner reliability was assessed using Cohen's Kappa (Cohen, 1960). For all items scored by two independent examiners (SE and IRH), where differences in scores occurred, both examiners discussed the score and arrived at an agreed score. The default position was to award the lower score wherever an agreement could not be reached. Therefore, the assessment result may be a conservative estimate.

The endodontic training blocks (Dentsply, Maillefer, Switzerland) are transparent plastic blocks that have been designed to simulate a patient's root canal for practicing shaping techniques. It is difficult to assess technical skill in endodontics using endodontic training blocks alone as they present a highly artificial situation and their limitations are recognised. However, they have been used for training in other studies (Dahlström *et al.,* 2015; Dahlström *et al.,* 2011; Reit *et al.,* 2007). This did allow estimation of change in technical skill of preparing an endodontic training block during the course, giving information concerning technical ability in using instruments and materials but also some information regarding knowledge of how the participants apply these technical skills. Difficulties achieving ideal taper of the preparation and occurrence of procedural errors were also highlighted. Initially, obturation of the prepared canal in the endodontic training block was encouraged. However, as a heated vertical compaction method of obturation began to be used during the course it became impossible obturate the endodontic training blocks as they began to melt and alter the shape of the preparation. As a result patency could not be assessed in each case. Some of the blocks completed on the first day of the course have been obturated and the remainder have not, leading to an inconsistency. If all of the endodontic training blocks were not obturated it may have been appropriate to check the working length has been reached using a hand file, however this step was not carried out in this study. Although, every effort was made to randomise and blind the examiner to the course participant and the stage in training, some of the endodontic training blocks were obturated at the beginning of the course and not at the end, which is a source of bias.

Performance on the task prior to training was compared to that following training. Ideally the blocks should have been compared to a gold standard block with objective measurement using three-dimensional computer imaging or as previous studies have used, impressions taken of the prepared canals to objectively assess shape of preparations (Abou-Rass & Jastrab, 1982). However, these were not practical for this project as the blocks were prepared and obturated as part of the learning experience and removal of the obturation material to assess canal shape may alter the preparation introducing further confounding factors. If this were to be performed again, obturation should not be carried out and an impression of the canal taken to assess shape and the apical stop (with possibility of scanning the impression and using computer software to assess the preparation against a gold standard). In future studies, tooth shaped blocks with Knoop hardness comparable to that of tooth substance could be used and specifically advised to prepare the canal system and stop short of obturation of the canals.

4.10.3 Quality of Endodontic Treatment Performed on Patients (*in vivo*)

The quality of root canal treatment was assessed in terms of the clinical treatment process and the appearance of the root canal filling as seen radiographically at the end of treatment. The first ten cases treated during the course and the last ten cases treated during the course were collected or this purpose, using the logbooks and radiographs taken during treatment. The logbook forms were designed to allow good record keeping and not necessarily for this study but are based upon best current clinical practice (General Dental Council, 1997) and were kept as part of the course (this included the radiographs). There was a reliance on the course participants to provide accurate logbooks and both digital and plain film radiographs were submitted.

No attempt was made to ascertain the patient perspective for these cases. Treatment process was scored (Table 19) and the quality of the root filling as seen radiographically was scored (Table 21). Healing will not be assessed as part of this exercise. Data gathered were entered into an Excel™ (Microsoft Office 2010, Microsoft, Redmond, WA, USA) spread sheet for further analysis. The examiners were blinded to the treatment process and the stage of training of the DES when assessing the quality of root canal treatment radiographically. The two examiners also scored each tooth for complexity (Table 25). Inter- and intra-examiner reliability was assessed using Cohen's Kappa (Cohen, 1960). For all items scored by two independent examiners, where differences in scores occurred, both examiners discussed the score and arrived at an agreed score. The default position was to award the lower score wherever an agreement could not be reached. Therefore the results may be a conservative representation. The limitations of radiographic analysis in a primary care setting have been discussed previously in section 4.5.

4.10.3.1 Quality of the Clinical Treatment Process

Quality of the 'treatment process' related to the quality aspects of clinical treatment provision, which may influence the outcome of treatment. Quality of the treatment provided was inferred from the information gathered regarding the procedure itself and scored for the use of rubber dam, apex locators, patency filing and irrigants (as per Table 19). Data were gathered from the endodontic treatment summary form (Figure 8) that was completed by each DES and submitted to the researcher for all patients recruited to the study. There was a reliance on the accurate information being entered into the logbook by the participating dentist and there may have been bias in the knowledge that the patient has consented to partake in this research. Ideally ten percent of the patients who consented to take part should have the logbook summary compared with the clinical notes (although, again there would be reliance on accurate record keeping), however this was not logistically possible as part of this study. In order to overcome bias, a separate research assistant could have taken consent from patients and collated the logbook data for those patients participating in the study, thereby blinding the dentist to which patients were part of the study.

4.10.3.2 Radiographic Quality of the Root Canal Filling

Technical skills were also assessed by scoring the radiographic appearance of the root canal filling with emphasis on the occurrence and correction of procedural errors, the presence of voids, and the extent and taper of the obturation (Table 21). These are routinely recorded by way of the radiographs taken after completion of the root canal treatment, as part of the care that is being provided. Radiographs taken as part of the treatment for those patients recruited into the study were forwarded to the researcher (SE). No additional radiographs were taken solely for the purpose of this research. As discussed previously, there may have been bias present in knowing which patients have consented to participating in the study. Radiographic data collection was dependent on the quality of the radiographs and standardisation of the radiographs. The limitations of radiographic analysis in primary care have already been discussed in section 4.5. Two examiners (SE and IRH) independently assessed all of the radiographs (independent to the DES course and independent to each other). Pre- and post-operative radiographs were examined. All examiners were trained and pre-calibrated using a selection of radiographs and Kappa scored (as described in Section 4.8).

4.10.3.3 Evidence of Clinical and Radiographic Healing

Healing as assessed radiographically was scored as described in Table 23. Healing as seen clinically was scored as described in Table 24 using data collected from logbooks. The outcome of root canal treatment in this study was measured by assessing clinical signs and symptoms as well as radiographic development or resolution of apical pathology. There was possible bias in knowing which patients consented to participating in this study when completing logbook forms and providing treatment, that could not be avoided in this pilot study.

4.10.3.4 Oral Health Impact Profile in Endodontics Questionnaires

In order to evaluate clinical and patient based outcome in relation to clinical skills, patient perception was investigated using a patient satisfaction/experience questionnaire drawn from the General Practice Patient Satisfaction Questionnaire used by Gallagher *et al.* (2010) in a survey of Oral Surgery Specialist Services in primary dental care in South East London. The written, self-completed, participant (patient) questionnaire used a Likert-type scale for measuring patient perception of their oral health at various time points. This was further developed for form the Oral Health Impact Profile-Endodontic Outcome Measure [OHIP-EOM] (Rasheed, 2012).

In this study, there were inherent difficulties involved in response rate of surveys. Following principles outlined by Dillman *et al.* (2009) efforts were made to contact patients consenting to take part in the survey up to a maximum of three times. Contact was made via telephone/postal services/email depending on patient preference. Due to the reliance on eight course participants recruiting patients for this study there was significant delay and difficulty accumulating a large sample size.

There were limitations to the questionnaire used in this study, especially in understanding whether changes in QoL are related to tooth related changes or due to changes in other aspects of participants' lives. Questions to understand the antecedents that may influence response shift would be useful. The questionnaire was given to only those who were to undergo endodontic treatment. Ideally a similar group of individuals without tooth related problems should have also been sampled. The questionnaire used in this study did not record the date on which the questionnaire was completed and the date on which the treatment was completed, and this is a limitation of its design, which should be altered for future studies.

4.10.3.4.1 Pre-Treatment Questionnaire

Following written consent, patients were given a confidential questionnaire (Appendix S) to complete in the waiting room prior to treatment. Completed questionnaires were placed in the business reply envelope provided and sealed. The sealed envelopes were then either posted by the patient or handed to the receptionist in the practice who posted the envelopes at the end of each day. This should have taken no longer than 15 minutes. The address on the envelopes was that of the data collection team for this project at Kings College London. It was anticipated that there might be a number of cases where the DES participants treat their own patients and removal of caries may lead to the need for root canal treatment. In most instances this can be predicted by the dentist and would require consent for research and completion of the questionnaire prior to initiating root canal treatment. However cases where it is unexpected, therefore prior consent and questionnaire completion cannot be achieved, were excluded from the study.

4.10.3.4.2 Post-Treatment Questionnaire

The second questionnaire (post treatment questionnaire, Appendix T) was given to the patient at the completion of treatment. Treatment may have been completed in one or more visits. When the root filling had been completed, the patient was asked to take the second questionnaire home, complete it (after anaesthesia had worn off) within one month after treatment and return it in the business reply envelope provided. Ideally for those patients that failed to return the questionnaire, an e-mail or postal reminder was to be sent at 2 weeks post completion of treatment and then a further reminder was to be sent at 4 weeks post completion of treatment. However the questionnaires and the treatment details were not returned promptly and it was not possible to send such reminders. There was a reliance on the dentist to distribute and collect the questionnaires in a timely manner.

4.10.3.4.3 Follow-Up Questionnaire

The third confidential follow-up questionnaire (Appendix U) was given personally at the follow-up appointment, emailed or posted to the patient (about 12 months post completion of endodontic treatment) with a business reply envelope to return the questionnaire to the data collection team at Kings College London. If patients failed to return the questionnaire within three weeks of posting/emailing, 2nd and 3rd reminders were to be posted with a copy of the questionnaire on two separate occasions for all participants, as electronic response rates have been shown to be significantly lower than postal responses (Dillman *et al.,* 2009). Due to the time constraints on data collection, only a second reminder was possible before the end of January 2014.

Where ever possible telephone interviews were to be avoided as to avoid influencing the patient's answers. However, those that failed to respond to written requests, and had provided contact telephone number attempts were made to contact by telephone and collect responses to the questionnaire over the telephone. For non-English speaking patients, access to an interpreter will be facilitated should they wish to participate in this survey (Language Line London).

4.10.4 Follow-Up of Patients Treated Post-Training

At follow-up (approximately 12 months post completion of treatment), clinical and radiographic data from the review appointment (logbook data) were collected. It was anticipated that the recall rate would be around 35% from completion of endodontic treatment to 1-year review (Farzaneh *et al.,* 2004).

4.10.5 Scoring of Radiographs

It is routine practice to use radiographs to evaluate the appearance of completed root fillings and to measure healing as seen radiographically. In an ideal scenario all aspects would have been standardised and reproducible in order to be able to adequately assess healing as seen radiographically. Ideally all radiographs should be from the same system to be standardised. Digital should be viewed on the original screen recommended by the manufacturer using the software provided with the system and saved in unchangeable form.

Eight course participants were involved in this study and a variety of radiographic methods were employed. Standardisation of radiographs was a logistical issue and no attempt was made to standardise the radiographic equipment or clinicians. Course teaching involved the use of radiographic assessment using film holders as standard to reduce the risk of errors related to film positioning. The ideal standardised and reproducible radiographs would be taken using bespoke putty matrices for positioning and one radiographic system. However this was logistically and financially difficult to administer in a busy NHS dental practice and this research attempts to gain a snap shot of what is occurring in the 'real world' at a general practice level. Inherent within this are the problems of reliability, clinician and patient compliance, and over burdening them with specificities relating to research, which may in fact lead to bias resulting from this research influencing current practice. Some of the course participants used conventional plain film radiography; while others used digital radiography from the beginning of the course. Some moved from plain film radiography to digital radiography in the duration of the training course. A variety of digital radiographic systems were being employed with system specific viewing screens and software. It was assumed that the clinician, trained nurse or radiographer in the practice would take these radiographs. The use of CBCT was not practical to use in this study as none of the dentists had access to CBCT in general practice.

All plain films should be retained and viewed on a fluorescent light box under magnification of 2.5 in a darkened room (Ng *et al.,* 2011) and all digital radiographs should be saved in their raw format and viewed using a high-resolution colour cathode ray tube monitor. Radiographs used in this study included plain films photographed on a fluorescent viewing box without magnification and digitised into JPEG format. The digital radiographs were exported from the various digital systems and saved in JPEG form (opinions gathered from two independent radiologists). As actual measurements were not made from the radiographs, little further information was to be gained from saving these files in either RAW or TIFF forms. It was assumed that the radiographs provided by the course participants were not altered in any way. The plain films were photographed using a Single Lens Reflex camera (Nikon D90) with the film placed on a bright-light viewing screen in a darkened room. The plain films and digital films were then saved as JPEGs and examined on a single screen (13” MacBook Pro, Apple Inc., Cupertino, CA, USA). Black card with a window was used to ensure consistent magnification was used for all radiographic scoring and to eliminate the background light emitted by the screen (Orafi *et al.,* 2010).

The radiographs were assessed according to the criteria outlined in the guidelines from the National Radiation Protection Board (Department of Health/National Radiation Protection Board 2001) and an appropriate score given (Table 32). If the radiographs scored -1, they were considered not of diagnostic quality and therefore not scored for the other domains.

Table 32: Definition of good, satisfactory and poor quality radiographs

Good quality radiograph (excellent) **Score 1**	**Satisfactory quality radiograph (diagnostically acceptable)** **Score 0**	**Poor quality radiograph (unacceptable)** **Score -1**
No errors of patient preparation, exposure, positioning, processing or film handling	Some errors of patient preparation, exposure, positioning, processing or film handling, but which do not detract from the diagnostic utility of the radiograph	Errors of patient preparation, exposure, positioning, processing, or film handling, which render the radiograph diagnostically unacceptable

Department of Health/National Radiation Protection Board guidelines 2001

4.10.6 Participant (Patients) Perception of the Service

Section 10.4.3.4 described written, self-completed, questionnaires,, which also collated demographic data and patient views of the service they received as part of being referred to a specific service for receiving root canal treatment.

4.10.7 Participant (Dentists) Perception of the Training

Participating dentists views were collected by means of a free text anonymised questionnaire (Appendix V). One of the course teachers (SE) collected this data and therefore questionnaires have been selected to capture this data as opposed to interviews or focus groups. Maintaining anonymity allowed the participants to be honest about their experiences and suggestions for improvement. Independent assessors conducted focus groups and interviews as part of a wider service evaluation (Al-Haboubi *et al.,* 2014; Al-Haboubi *et al.,* 2016). The questionnaires were collected prior to the participants receiving their final grades to avoid bias. It was appreciated that responses at different times during the course may have varied. The questions were open ended with room to elaborate on the answers, and were developed to capture a range of views on the factors affecting participant experience, the effect of the National Health Service (NHS) arrangements on the experience of providing an endodontic service within NHS primary care, barriers to providing endodontic treatment in NHS primary care, and the perceived impact of the pilot training programme on themselves, their organisation and their patients. Ideally these open ended questions should be developed using an expert panel in conjunction with focus groups or interviews to better understand the participants understanding of the questions, their intent and appropriateness of the response format, followed by revision and piloting of the instrument (Mullens & Kasprzyk, 1996). Log diaries kept throughout the course may have been a suitable method of validation of the questionnaire and these would be better than a single questionnaire which is reliant on long term memory and summative ability of the participant. However questionnaires of this nature are acceptable methods of ascertaining clinicians' views (McColl *et al.,* 2001; Burns *et al.,* 2008) and the validity of the anonymised self-completed written questionnaires can be assessed against participant views that were gathered from in depth interviews as part of a larger service evaluation of the course.

Participating dentists were e-mailed with the questionnaire following completion of the training course (April 2011) and were invited to complete the questionnaire anonymously and either drop the questionnaire in a sealed unmarked envelope on the feedback day (April 2011) or post the questionnaire back to the Primary Investigator. It was advised that the questionnaire be filled in using a computer to maintain anonymity. Demographics were not collected as part of the questionnaire as this would allow identification of the individual participant. All responses to all questions were transcribed verbatim and tabulated in a data spread sheet using Microsoft Excel™ (Microsoft Office 2010, Microsoft, Redmond, WA, USA).

4.10.8 Training Course Cost Estimation

This course may be an appropriate method of improving the endodontic skills of general dental practitioners and it would be prudent to consider the cost implications in relation to other speciality training courses to determine the feasibility of using this model in future. The costs of the course delivery were determined by collecting data on the costs of teaching, materials and equipment. The costs were estimates only and there were difficulties in accessing the actual costs as a result of deconstruction of the Primary Care Trusts involved as part of modernising the NHS during this time.

4.11 Data Analysis

All data were initially entered into an Excel (Microsoft Office 2010, Microsoft, Redmond, WA, USA) spread sheet, proofed and locked. SPSS (IBM Corporation, Armonk, NY, USA) v22 was used for further analysis. The unit of analysis has been specified for each section in Table 33.

4.11.1 Academic Knowledge Score from Course Assessments

Descriptive statistics were calculated for the Academic scores. The unit of analysis was the dentist. Data appeared not to be distributed normally for all of the separate domains therefore a non-parametric test for two related samples were used (Wilcoxon's Rank test). Data for total scores and mean score for each domain appeared to be distributed normally, therefore these were compared using the paired t-test was used for comparing two paired groups of parametric data (after testing for normality). Data were not analysed at the level of individual dentists.

4.11.2 Quality Performance on Endodontic Training Blocks (*in vitro*)

The proportion of endodontic training blocks receiving each score was calculated for each time point and the change from Year 0 to Year 2 was analysed. The unit of analysis was the dentist. The McNemar test was used to calculate the statistical significance for the change from Year 0 to Year 2. The Mann-Whitney U test was used to calculate the statistical significance of the difference in mean total scores from Year 0 to Year 2 (data were considered not to be normally distributed when tested). The Z-test was used to calculate the statistical significance of the difference from Year 0 to Year 2 (data were considered not to be normally distributed when tested).

4.11.3 Quality of Endodontic Treatment Performed on Patients (*in vivo*)

The proportion of teeth receiving each score was calculated for each time point and the change from Year 0 to Year 2 was analysed. The unit of analysis was the patient and secondarily the dentist. Z-test was used to compare proportions of ideal scores and calculate the statistical significance of the difference from Year 0 to Year 2. The Mann-Whitney U test was used to calculate the statistical significance of the difference in mean total scores from Year 0 to Year 2 (data were considered not to be normally distributed when tested). The Z-test was used to calculate the statistical significance of the difference from Year 0 to Year 2 (data were considered not to be normally distributed when tested).

The unit of analysis was the endodontic training block (*in vitro*) and each tooth (*in vivo*). The mean score for endodontic training blocks, treatment process and appearance of root filling as seen radiographically for each participating dentist was compared at Year 0 and Year 2 without further statistical analysis. The mean total score for treatment process plus appearance of the root filling as seen radiographically was calculated and a comparison made between Year 0 and Year 2 without further statistical analysis.

For patients studied post completion of the course, the proportion of teeth receiving each score was calculated for post-training cases and compared to that for Year 2. The unit of analysis was the patient and secondarily the dentist. The Z-test was used to calculate the statistical significance of the difference from Year 2 to post-training (data were considered not to be normally distributed when tested). The Mann-Whitney U test was used to calculate the statistical significance of the difference in mean total scores from Year 2 to post-training (data were considered not to be normally distributed when tested).

Each tooth (not each root) was used as the unit of evaluation for scoring, as it would be difficult to localise failure of treatment in a multi-rooted tooth to any one root. The patient was used as the overall unit of measure in the analysis. If any of the patients had more than one tooth treated, only one tooth was randomly selected for inclusion in analysis. The mean total summative scores for all domains were calculated as per Table 26 and no further statistical analysis was performed. The summative scores of OHIP-EOM for separate domains of health and overall health (all domains) were calculated from the OHIP-EOM questionnaire results. The change in OHIP-EOM scores were descriptively analysed for each time period.

4.11.4 Participant (Patients) Perception of the Service

In order to analyse the patient views of the service, the relevant data from the questionnaires returned were entered into an Excel (Microsoft Office 2010) spread sheet, proofed and locked. SPSS (IBM Corporation, Armonk, NY, USA) v22 was used for further analysis. The analysis was quantitative and purely descriptive, with no further statistical analysis performed.

4.11.5 Participant (Dentists) Perception of the Training

Qualitative data from the DES questionnaires were analysed using Framework Analysis (Ritchie & Lewis 2003). Framework analysis allowed for systematic and visible stages to the data analysis process: familiarisation; identification of a provisional thematic framework; indexing; charting; and mapping and interpretation. Framework analysis follows a standard 5-stage process. In the initial familiarisation stage responses were read and re-read, and key emerging themes and ideas listed framed by areas of the topic guide. A provisional thematic framework identifying key issues, concepts and themes were then developed, so that data can be examined and referenced to themes through coding. In the data indexing process, the researcher applied the index of the thematic framework to the transcriptions. During the charting process, data were rearranged through constant comparison, and the thematic framework expanded in light of the application of the data. During the mapping and interpretation stage, data were synthesised to detect and define concepts that allow mapping the range and nature of experiences as well as find patterns and associations that may impact participant experience.

4.11.6 Course Cost Estimation

Total cost of the course was estimated using a summative approach. Average cost per dentist were calculated and compared to that of enrolling in recognised monospecialty training in endodontics.

4.12 Summary of Materials and Methods

This chapter detailed the various elements of methodology used in the different parts of this pilot and feasibility study (Table 33). The instruments to capture data and assess outcome have been described.

Table 33: Summary of research questions with unit of analysis, point of comparison, sample size

Research question		Unit of Analysis	Point of comparison	N =
I	In GDPs, does additional training/experience in endodontic techniques improve their performance *in vitro* (endodontic training blocks) and *in vivo* (clinical cases using data from logbook and radiographs) compared to their performance before training/experience?	Dentists enrolled in study	The same dentists at two time points (at the beginning and end of the course)	8 dentists
II	What is the quality of root canal treatment provided by this cohort of GDPs with enhanced skills in root canal treatments (post completion of training)?	Patients enrolled in the study	None (descriptive)	135 patients
III	What are the views of patients on the service they received after this initiative?	Patients	None (descriptive)	135 patients
IV	What are the views of course participants on this training and implications for their patients in the National Health System (NHS)?	Dentists	None (descriptive)	8 dentists
V	What was the cost of providing this model of training?	Dentists	None (descriptive)	8 dentists

In this section, learning for future studies was outlined and will be elaborated on in the discussion. The following section presents findings from this pilot to inform further research in this area. The results for objective one of this research are presented in Chapter five, describing the findings related to change in skills during the course of training and Chapter six, detailing the maintenance of skills post-training and the patient related outcomes. The results for objective two are described in Chapter seven, eight and nine, outlining the patients' views of the service, the dentists' views of their training and the estimated costs of this training initiative respectively. The loss to follow-up during various parts of this study is shown in Figure 13.

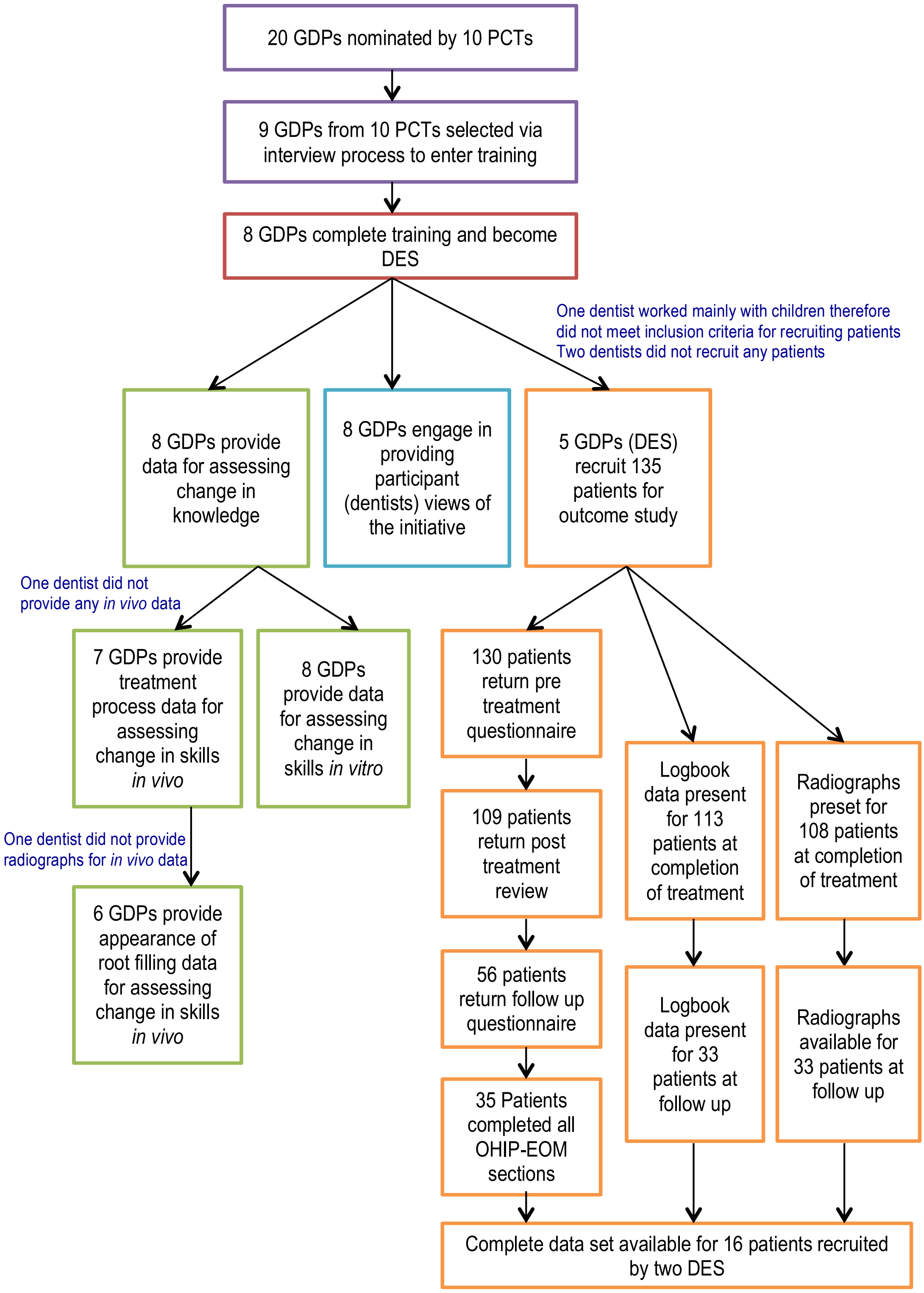

Figure 13: Loss to follow-up during the study

Chapter 5: Results (Part 1): Change in Skills

This pilot and feasibility study tested the measuring tools developed and the potential problems with using the previously described methodology in this mixed methods research outlined in Chapter 4. This Chapter presents the results for the assessment of change in skills with additional training and experience (Objective 1). The change in skills following additional training was assessed using the course assessments (academic knowledge score), endodontic training block scores (*in vitro*) and the first and last ten teeth root filled during the course (*in vivo*). The unit of analysis was the dentist participating/being training in the course. In all analyses incomplete data were excluded from the analysis.

5.1 Demographic Data for Participating Dentists

Eight dentists (4 male, 4 female) with an age ranging from 27- 51 years (mean 36 years, SD=8.2 years) participated in the course and contributed to data. The mean time since qualifying as a dentist was 12.1 years (SD=8.2 years, range 4-27 years). Six of the dentists worked in General Practice settings and two worked within the Community Dental Services. One of the participants had undertaken previous post-graduate training in endodontics. A ninth dentist, who participated in this study, failed to complete the end of Year 1 examination with a satisfactorily grade and therefore did not complete the course and is excluded from the following data sets. During the development of the course, it was made clear to the delegates that in order to complete the course, a high standard would need to be met and enrolling in the training course would not guarantee completion of the course without satisfactory completion of the assessments.

5.2 Complexity Level of Cases Treated

For *in vivo* analysis, information reported in the logbook maintained for each tooth and the preoperative radiographs of each tooth were used to determine the complexity of teeth treated. When incomplete data sets were considered, the total complexity score for the first ten cases (Year 0) was 345 points (n=60, mean=5.75, SD=3.08, range 0-11) and that for the last ten cases (Year 2) was 411 (n=64, mean=6.42, SD=2.58, range 0-10). A score of 6 to 15 points was considered 'moderate complexity' (Al-Haboubi *et al.,* 2014). Complete data (radiographic and logbook data) on complexity were available for 28% of cases for Year 0 and 23% of cases for Year 2. There was no significant difference in mean complexity score from Year 0 (mean 6.29 SD=2.54) to Year 2 (mean 7.13 SD=2.30). There were no significant differences in the mean complexity scores for those with complete and incomplete data. This was in keeping with the triaging process for teeth of moderate complexity being referred for treatment within this service (Al-Haboubi *et al.,* 2014).

5.3 Assessment of Academic Knowledge of Participant Dentists

The eight participant trainee Dentists with Enhanced Skills in Endodontics were assessed across a number of domains in a *viva voce* examination (by one internal and one external examiner) at the end of Year 1 and again at the end of Year 2. Assessment scores shown in Table 34 are the mean scores for the two examiners, as the examiners did not agree one score but scored each domain independently. As data did not appear to show a normal distribution for all of the separate domains, a non-parametric test for two related samples were used (Wilcoxon's Rank test). Statistically significant differences in scores from Year 1 to Year 2 were observed in Clinical Assessment, Investigations & Referrals and Professionalism. Data for total scores and mean score for each domain appeared to be distributed normally, therefore a parametric test for two related samples was used (paired T-test). There was no significant difference in scores from Year 1 to Year 2 for all but two of the dentists (Figure 14). The score for the ninth dentist (mean examination score = 3, SD = 0.71) was not included in the end of Year 1 scores.

Table 34: Mean exam performance scores of all dentists scored by two examiners (one external and one internal) at the end of Year 1 examination and at the end of Year 2 examinations

Domain	Year 1	Year 2	P value	Statistically significant difference between Year 1 and Year 2
	Mean (SD)	Mean (SD)		
Medical record keeping	4.44 (0.17)	4.50 (0.27)	0.783*	
Clinical assessment	4.00 (0.27)	4.44 (0.32)	0.038*	Significant
Investigations & referrals	4.13 (0.23)	4.56 (0.32)	0.038*	Significant
Treatment	4.63 (0.58)	4.69 (0.37)	0.739*	
Follow-up and future planning	4.13 (0.23)	4.44 (0.32)	0.059*	
Professionalism	4.38 (0.44)	4.88 (0.64)	0.046*	Significant
Overall clinical judgement	4.31 (0.53)	4.63 (0.44)	0.160*	
Mean total score for all domains	4.29 (0.30)	4.59 (0.31)	0.056^	
Total score for all domains	30.00 (2.07)	32.12 (2.15)	0.056^	

*Wilcoxon's Rank test was used for comparing two paired groups of non-parametric data (when tested all domains revealed non normality)
^Paired T-test was used for comparing two paired groups of parametric data

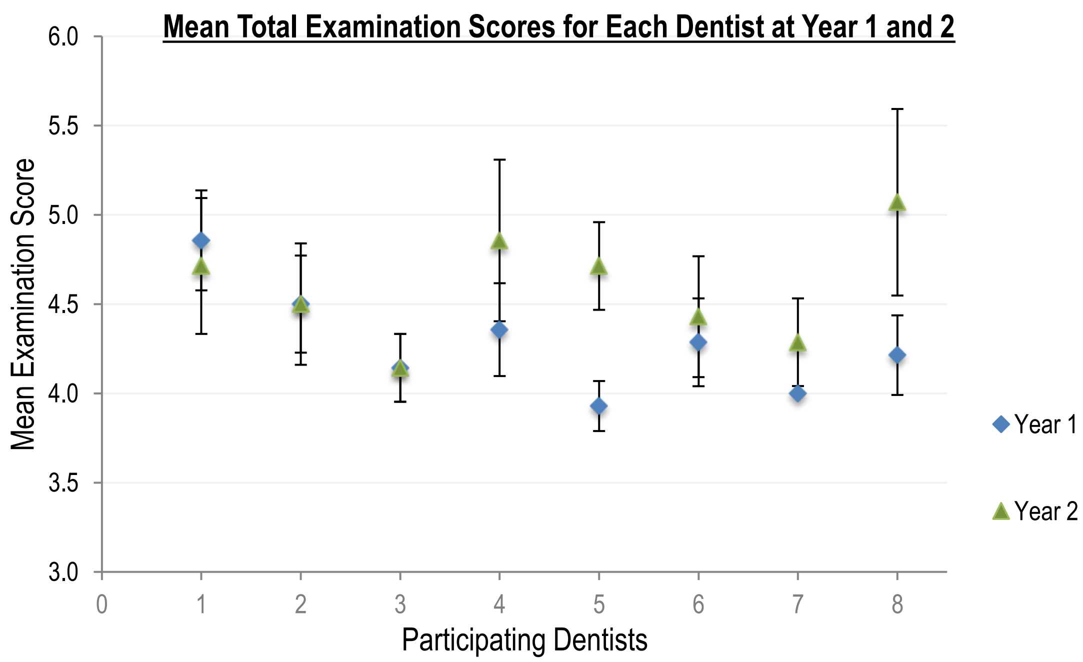

Figure 14: Mean total examination score for each of the participating dentists at Year 1 and Year 2 with 95% confidence intervals

5.4 Assessment of Performance on Endodontic Training Block (*in vitro*)

Technical skills acquired in endodontic training block (*in vitro*) training were assessed in four domains: 1. lack of procedural errors, 2. establishment of the correct working length (within 2mm of the apex), 3. taper and 4. shape achieved. Seven of the eight participants provided endodontic training blocks for all time periods (Year 0, Year 1 and Year 2). One participant failed to provide endodontic training blocks for Year 0 and Year 1 due to personal reasons and was only able to attend the examination but unable to stay for the whole day to complete the endodontic training blocks.

The mean total score for endodontic training blocks was 0.14 (n=7, SD=0.38) at Year 0, 1.43 (n=7, SD=1.27) at Year 1 and 2.25 (n=8, SD=1.04) at Year 2. There was a statistically significant difference in the mean total scores for the endodontic training blocks from Year 0 to Year 2. As the confidence intervals did not overlap and no further statistical analysis was required (Figure 15). The ninth dentist scored zero for all domains of the quality of endodontic training blocks at Year 0 and Year 1, and was excluded due to failure to complete the course.

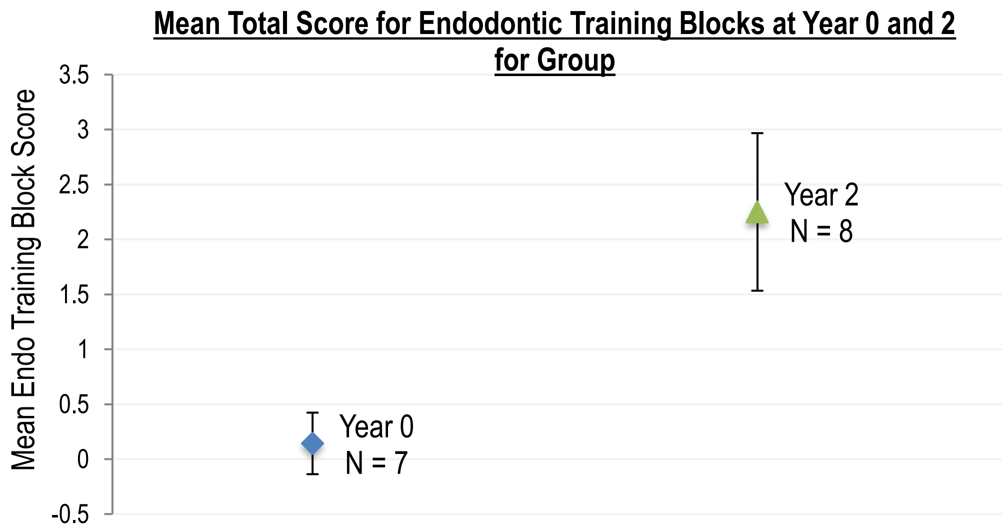

Figure 15: Mean total score for endodontic training blocks at Year 0 and Year 2 with 95% confidence intervals

There was an improvement in score from Year 0 to Year 1 and from Year 1 to Year 2 in all domains. Table 35 shows the improvement from Year 0 to Year 2. The increase was modest from Year 0 to Year 1 and then from Year 1 to Year 2. The total score increased by nine points from Year 0 to Year 1, eight points from Year 1 to Year 2 and by seventeen points from Year 0 to 2. Individually all dentists improved from Year 0 to Year 2. Data for Year 1 is shown in Appendix W.

Table 35: The proportion of endodontic training blocks receiving each score at Year 0 and Year 2 for all eight participants

<table>
<tr><th rowspan="2">Endo training block scores</th><th colspan="2">Procedural errors (Y=0, N=1)</th><th colspan="2">Working length (Y=1, N=0)</th><th colspan="2">Taper and Shape (Y=1, N=0)</th><th rowspan="2">Endo training block scores</th><th colspan="2">Total Scores (0=Poor, 3=Good)</th></tr>
<tr><th>Yr 0</th><th>Yr 2</th><th>Yr 0</th><th>Yr 2</th><th>Yr 0</th><th>Yr 2</th><th>Yr 0</th><th>Yr 2</th></tr>
<tr><td>N=</td><td>8</td><td>8</td><td>8</td><td>8</td><td>8</td><td>8</td><td>N=</td><td>8</td><td>8</td></tr>
<tr><td rowspan="2">0</td><td rowspan="2">7</td><td rowspan="2">3</td><td rowspan="2">6</td><td rowspan="2">0</td><td rowspan="2">7</td><td rowspan="2">3</td><td>0</td><td>6</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>3</td></tr>
<tr><td rowspan="2">1</td><td rowspan="2">0</td><td rowspan="2">5</td><td rowspan="2">1</td><td rowspan="2">8</td><td rowspan="2">0</td><td rowspan="2">5</td><td>2</td><td>0</td><td>0</td></tr>
<tr><td>3</td><td>0</td><td>5</td></tr>
<tr><td>Missing</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>Missing</td><td>1</td><td>0</td></tr>
<tr><td>Total Score</td><td>0</td><td>5</td><td>1</td><td>8</td><td>0</td><td>5</td><td>Total Score</td><td>1</td><td>18</td></tr>
<tr><td>P value*</td><td colspan="2">0.046</td><td colspan="2">0.014</td><td colspan="2">0.046</td><td>P value^</td><td colspan="2">0.0026</td></tr>
</table>

*McNemar test was used to calculate the statistical significance for the change from Year 0 to Year 2
^Mann-Whitney U test was used to calculate the statistical significance of the difference in mean total scores from Year 0 to Year 2 (data were considered not to be normally distributed when tested) and revealed statistical significance (U value =1.5 and for a $p<0.05$ the threshold was a u value of 10). Z-ratio revealed statistical significance and the p-value is shown

5.5 Assessment of Dentist Performance on Patients (*in vivo*)

All participant dentists provided treatment to patients during the training course. In order to assess the impact of additional endodontic training provided to the Participant Dentists, on the actual performance on patients, the first ten cases treated by each dentist contributed to data for Year 0 (beginning of the course) and the last ten cases treated by each dentist contributed to data for Year 2 (end of the course). All of the cases were scored for the technical quality of providing root canal filling employing two process measures. First, the clinical quality of the treatment provided (score for clinical treatment process) and second, the technical quality of the root filling as assessed by the appearance of the root filling seen on the post-operative radiographic (score for quality of the root filling as seen radiographically). The ‘Unit’ of analysis was primarily the tooth and secondarily the dentist. The information recorded in the logbooks maintained by the dentists and the corresponding radiographs of the cases were used for scoring.

5.5.1 Total Process Score for Quality of Root Canal Treatment

The total process score was an amalgamation of the score for the clinical process of providing treatment and that for the radiological appearance of the root filling (Table 31). Although there was no statistically significant difference in score from Year 0 to Year 2 when compared at a dentist level (Figure 16), the total process quality score for all dentists was 6.08 (n=50 teeth, n=7 dentists, SD=1.48, range 3-9) for Year 0 and 6.91 (n=61 teeth, n=7 dentists, SD=1.27, range 4-9) for Year 2, out of a total possible score of 9. There was a statistically significant difference in mean total process quality score for Year 0 when compared to Year 2 for all dentists (Figure 17). The following sections describe the breakdown of the total quality score for root canal treatment into the individual domains constituting the quality of the clinical process of root canal treatment (section 5.2.5.2) and the radiographic appearance of the root filling (section 5.2.5.3).

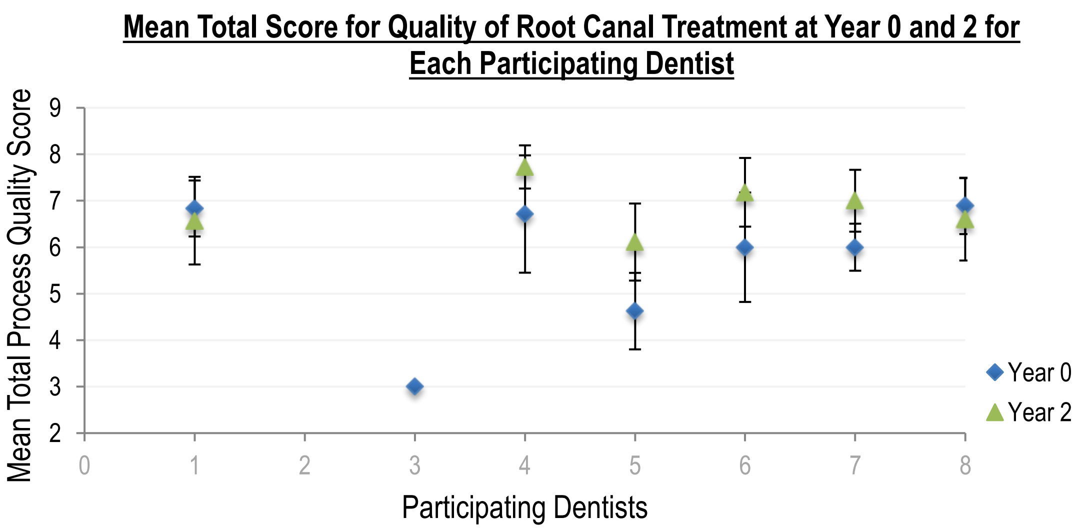

Figure 16: Mean total process quality score for each of the participating dentists at Year 0 and Year 2

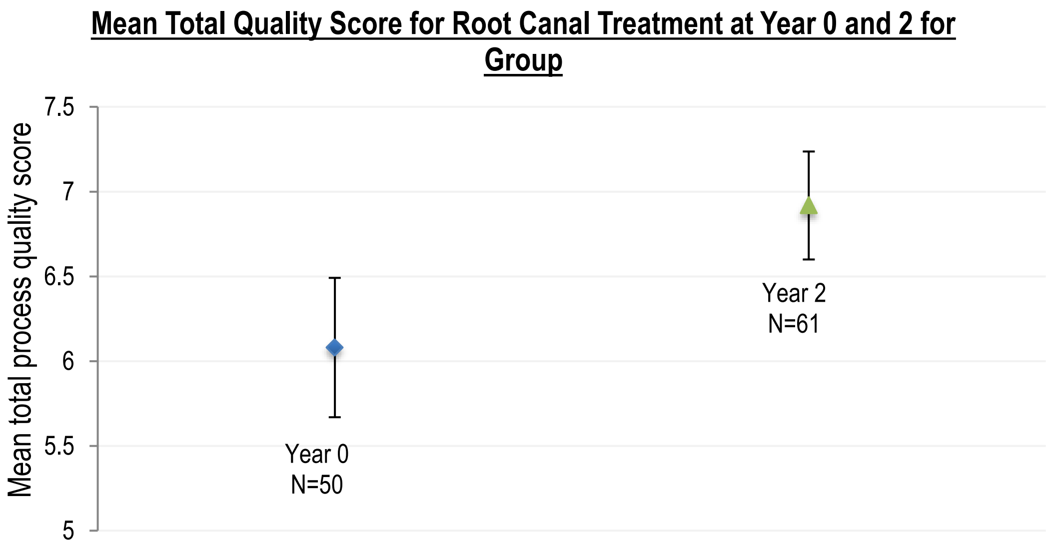

Figure 17: Mean total process quality score for all dentists at Year 0 and Year 2

5.5.2 Assessment of Quality of Clinical Care (Clinical Treatment Process)

Assessment of the root canal treatment procedure in a clinical setting represented the quality of the clinical treatment process. The number of cases contributing to the Treatment Process data is shown in Table 36 and these data were gathered from the contemporaneous logbook maintained by the dentist. In very few cases were there more than one tooth treated in the same patient. As this was analysed at tooth level and not patient level, all of these teeth were included in the analysis. Data were available for 130 teeth in total. At Year 2 the logbook forms were completed with less missing data. The technical quality of treatment consisted of four domains: 1. use of rubber dam, 2. use of an apex locator to establish working length, 3. use of patency filing technique to maintain apical patency and 4. use of two irrigants (sodium hypochlorite and Ethylenediaminetetraacetic acid). These contributed to a total score.

Table 36: Number of cases contributing data to clinical quality (Treatment Process Score)

	Year 0	**Year 2**
Total = 147 teeth (140 cases)	72 teeth (70 cases)	75 teeth (70 cases)
>1 tooth done in 6 cases	>1 tooth done in 2 cases	>1 tooth done in 4 cases
Completed logbook forms for 130 teeth	Completed logbook forms for 58 teeth	Completed logbook forms for 72 teeth

The mean Total Treatment Process score for the cohort of participating dentists increased from Year 0 to Year 2 and this was statistically significant (Figure 18). The Mean Total Treatment Process score at Year 0 was 3.67 (n= 58, SD=0.85) and at that at Year 2 were 4.18 (n=72, SD=0.51).

Figure 18: Mean total treatment process (quality of clinical treatment assessed using self-reported contemporaneous logbooks maintained by the dentists) score at Year 0 and Year 2

An increase in scores for treatment process in all domains from Year 0 to Year 2 was seen (Table 37). There was a 7% increase in the reported use of rubber dam as there were less missing data in Year 2, 29% increase in the reported use of an apex locator to establish a working length, 22% increase in the reported use of patency filing and a 15% increase in the reported use of the two recommended irrigants for disinfection during treatment. The change from Year 0 to Year 2 was statistically significant for all domains except for the use of rubber dam where no one reported not using rubber dam, which signifies an understanding of the quality standard (root canal treatment should not be performed without the use of rubber dam). Based on this evidence from this sample of dentists, the findings suggest an overall improvement from Year 0 to Year 2 and the adoption of better technique for provision of root canal treatment. The reported increase in the use of quality measures from the dentists' contemporaneous logbook data indicates either an actual increase in the use of the measure or at least a better understanding of the procedures to be followed during root canal treatment.

Table 37: The proportion of teeth receiving the each Treatment Process Score (data from contemporaneous logbooks maintained by the dentists) at both time points (Year 0 and Year 2) for the seven dentists who contributed to data

First & last cases score	**Rubber Dam** (Y=1, N=0)		**Apex locator used** (Y=1, N=0)		**Patency filed** (Y=1, N=0)		**First & last cases score**	**Irrigants used** (NaOCl + EDTA = 2, NaOCl=1, Anything else=0)		**First & last cases score**	**Total Score** (0=poor, 5=good)	
	Yr 0	Yr 2	Yr 0	Yr 2	Yr 0	Yr 2		Yr 0	Yr 2		Yr 0	Yr 2
N=	**64**	**72**	**69**	**75**	**65**	**74**	**N=**	**71**	**73**	**N=**	**58**	**72**
0	0	0	27	10	11	1	0	0	0	2	7	0
							1	59	49	3	12	4
1	64	72	42	65	54	73	2	12	24	4	32	51
										5	7	17
Missing	8	3	3	0	7	1	Missing	1	2	Missing	14	3
Total Score	**64**	**72**	**42**	**65**	**54**	**73**	**Total Score**	**83**	**97**	**Total Score**	**213**	**301**
Proportion	1	1	0.61	0.87	0.83	0.99	Proportion	0.17	0.33	Mean	3.67	4.18
P value*	**-**		**0.0004**		**0.0011**		**P value***	**0.0271**		**P value^**	**0.0016**	

*Z-test was used to compare proportions of ideal scores and calculate the statistical significance of the difference from Year 0 to Year 2
^Mann-Whitney U test was used to calculate the statistical significance of the difference in mean total scores from Year 0 to Year 2 (data were considered not to be normally distributed when tested). Z-ratio revealed statistical significance and the p-value is shown

The mean Total Treatment Process scores for each participating dentist for Year 0 and Year 2 are presented in Figure 19. One dentist did not contribute data for this analysis. All but one dentist improved in mean Total Treatment Process score from Year 0 to Year 2. It was noted that the 95% confidence interval error bars reduced in size for all participating dentists from Year 0 to Year 2. For three out of the seven dentists that contributed data, there was a significant change (improvement) in mean Total Treatment Process Scores from Year 0 to Year 2.

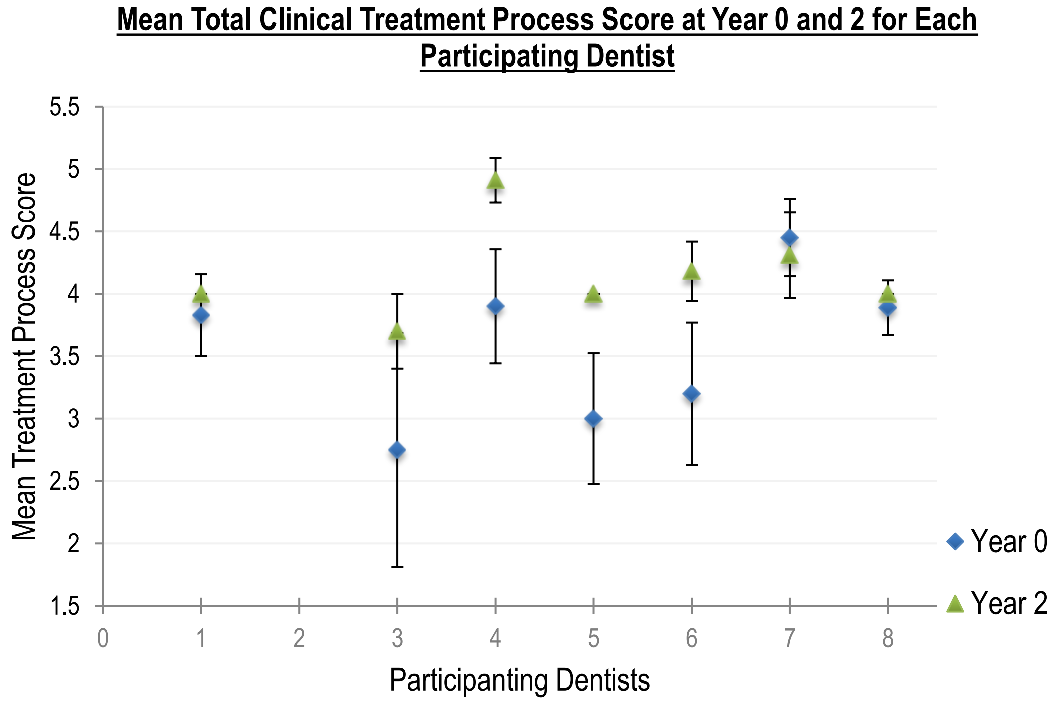

Figure 19: Mean total treatment process score (clinical quality of treatment) for Year 0 and Year 2 for each of the participating dentists with 95% Confidence Intervals

5.5.3 Radiographic Assessment of the Root Canal Filling (Quality of Root Filling)

The quality of root canal filling as seen on the post-operative radiograph represents another aspect of the process of providing root canal treatment, as described in section 4.4.7. A total of 133 teeth were assessed using radiographs. The breakdown of the contributing data for the assessment of the quality of the root filling as seen radiographically is shown in Table 38. The post-operative radiographs were used to score the radiographic quality of the treatment using four domains: 1. absence of procedural errors, 2. establishment of the correct working length (within 2mm of the apex), 3. achievement of the correct taper and shape achieved and 4. absence of voids within the root filling. A small number of radiographs (n=9 pre- and n=6 post-operative) were unusable due to their quality of the radiograph itself and therefore were recorded as such, effectively being treated as missing data in the analyses. There were nine unusable pre-operative radiographs in total (four in Year 0 and five in Year 2). It is possible that these were radiographs sent by the referring practitioner. There were six unusable post-operative radiographs in total (five at Year 0 and one at Year 2).

Table 38: Radiography of the Root Canal Filling: Number of records available

	Year 0	**Year 2**
Total = 133 teeth (126 cases)	68 teeth (66 cases)	65 teeth (60 cases)
>1 tooth treated in 6 cases	>1 tooth treated in 2 cases	>1 tooth treated in 4 cases
Pre-op rads available for 109 teeth (104 cases)	Pre-op rads available for 50 teeth (49 cases)	Pre-op rads available for 59 teeth (55 cases)
Post-op rads available for 128 teeth (121 cases)	Post-op rads available for 63 teeth (61 cases)	Post-op rads available for 65 teeth (60 cases)
Pre-op and post-op rads available for 104 teeth (99 cases)	Pre-op and post-op rads available for 45 teeth (44 cases)	Pre-op and post-op rads available for 59 teeth (55 cases)

Mean score for the appearance of the root filling as seen radiographically for the cohort of Participating Dentists showed a statistically insignificant increase from Year 0 to Year 2 (Figure 20). The mean total score for the appearance of the root filling as seen radiographically at Year 0 was 2.36 (n= 58, SD=1.15) and at that at Year 2 was 2.67 (n=64, SD=1.08). At Year 2 there were fewer unusable radiographs; however a similar number of missing radiographs.

Total score for each domain increased from Year 0 to Year 2 except for teeth with voids within the root filling, which increased by 7%. There was an 11% reduction in procedural errors, 19% increase in the number of cases where the correct working length was achieved and 9% increase in achieving the correct shape. The overall score increased by 34 points (Table 39). There was a statistically significant difference in the change in score for establishing the correct working length from Year 0 to Year 2.

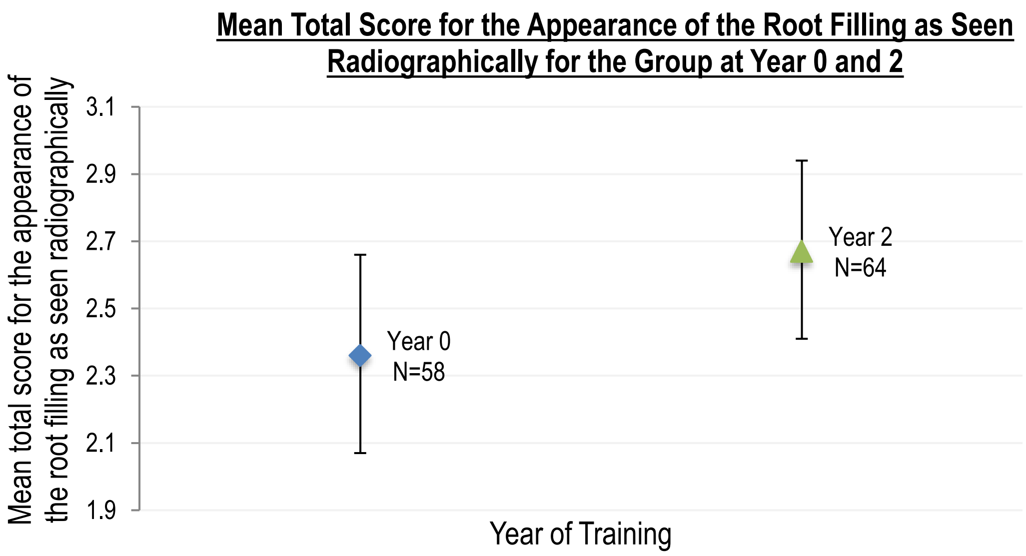

Figure 20: Mean score for the appearance of the root filling as seen radiographically at Year 0 and Year 2 with 95% CI

Table 39: The proportion of teeth receiving each score for the appearance of the root filling as seen radiographically (from post-operative radiographs scored independently by two examiners) at both time points (Year 0 and Year 2) for seven dentists who contributed to data

First & last cases score	Procedural errors (Y=0, N=1)		Working length (Y=1, N=0)		Taper and Shape (Y=1, N=0)		Voids (Y=0, N=1)	
	Yr 0	Yr 2	Yr 0	Yr 2	Yr 0	Yr 2	Yr 0	Yr 2
N=	**58**	**64**	**58**	**64**	**58**	**64**	**58**	**64**
0	17	12	28	19	29	26	21	28
1	41	52	30	45	29	38	37	36
Unusable	5	1	5	1	5	1	5	1
Missing	9	10	9	10	9	10	9	10
Total Score	**41**	**52**	**30**	**45**	**29**	**38**	**37**	**36**
Proportions	0.71	0.81	0.52	0.70	0.5	0.59	0.64	0.56
P value*	0.171		**0.035**		0.298		0.395	

First & last cases total score	Overall (0=poor, 4=good)	
	Yr 0	Yr 2
N=	**58**	**64**
0	1	2
1	17	10
2	11	9
3	18	29
4	11	14
Unusable	5	1
Missing	29	30
Total Score	**137**	**171**
Mean	2.36	2.67
P value^	0.139	

*Z-test was used to compare proportions of the ideal scores and calculate the statistical significance of the difference from Year 0 to Year 2
^Mann-Whitney U test was used to calculate the statistical significance of the difference in mean total scores from Year 0 to Year 2 (data were considered not to be normally distributed when tested). Z-ratio revealed no statistical significance and the p-value is shown

Mean total scores for the appearance of the root filling as seen radiographically for each participating dentist for Year 0 and Year 2 are shown in Figure 21. Two dentists did not contribute any data for this analysis, as one dentist did not provide any cases and the other dentist provided only 2 cases, one of which was unusable. It is possible that these dentists saw this research from being removed from those that commissioned and facilitated their training, and therefore, did not feel an obligation to contribute data to this study. Three dentists improved in mean Total Radiographic Outcome score from Year 0 to Year 2. For one of the six dentists that contributed data, there was a significant change (improvement) in mean total scores for the appearance of the root filling as seen radiographically from Year 0 to Year 2.

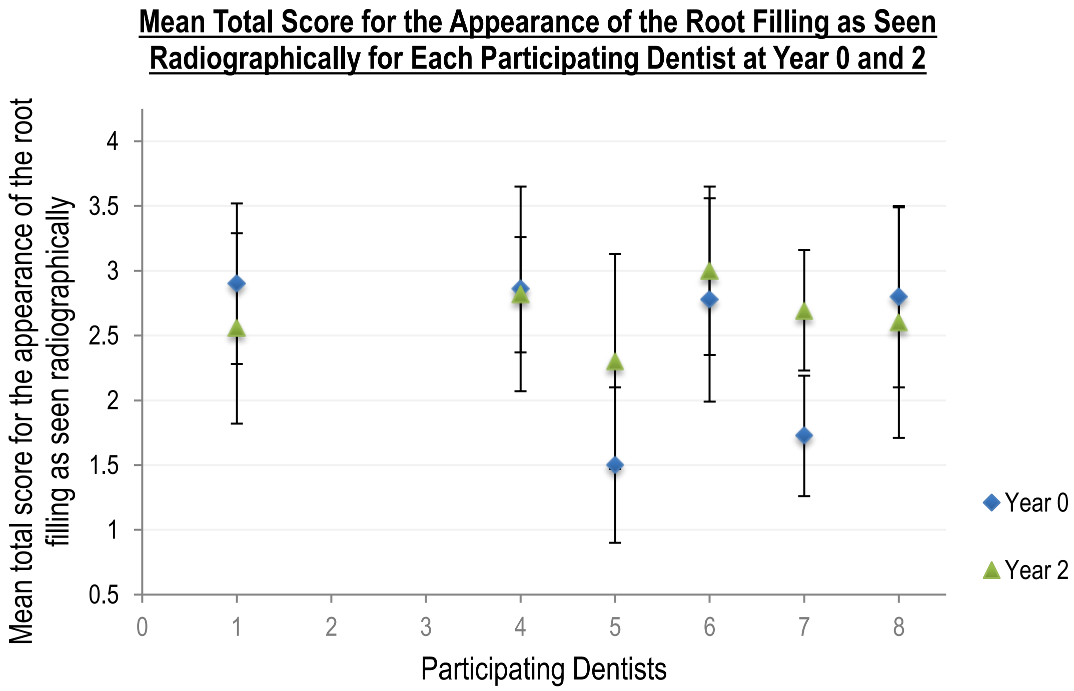

Figure 21: Mean score for the appearance of the root filling as seen radiographically for Year 0 and Year 2 for each of the participating dentists with 95% Confidence Intervals

5.6 Summary of Results for Change in Skills

The summary conclusion of the Change of Skill component of this study was that it is possible to collaborate training with providing clinical care to generate research data. It was also concluded that data could be collected as part of training to assess change in skills gained from training. The scoring systems developed for this purpose were shown to be useful.

Pilot data from this study suggest that, in General Dental Practitioners, the provision of additional training/experience in endodontic techniques does improve their performance in some domains of knowledge (clinical assessment, investigations and referrals and professionalism) and in all domains measured *in vitro* (endodontic training blocks) when compared to their performance before training/experience. *In vivo,* there was no significant difference in the total complexity scores for the teeth treated in Year 0 and Year 2 as intended. Participants' performance *in vivo* also improved for all domains of treatment process except the use of rubber dam, which was already high. Although overall scored improved, there was no statistically significant difference in the mean total process quality score from Year 0 to Year 2. Additional training improved the quality of the root filling as seen on post-operative radiographs in the domain of establishing the correct working length; however, in this sample, although the overall score for this two-dimensional view of the final root filling increased it did not improve significantly.

The following section investigates whether it is possible to assess if skills gained from additional training can be maintained following completion of training, for patients' treated in primary care and explores possibility of collecting data on the outcome of treatment, as a direct measure of the outcome of training.

Chapter 6: Results (Part 2): Outcome of Treatment

Part of the first objective of this research was to also determine if it possible to assess whether skills are retained following completion of training and whether that has an effect on the outcome of treatment provided, in terms of clinical, radiographic and patient related outcomes. This chapter presents data for post-training maintenance of skills gained from additional training and its impact on healing as well as patients' oral health.

Retention of skills post-training was assessed using the same domains as those for *in vivo* change in skills (Chapter 5), but with the patient as unit of analysis and not the individual tooth. As in Chapter 5, information recorded in logbooks maintained by the Participating Dentists and the corresponding radiographs of the cases were used to establish scores for the quality of the treatment (quality of clinical treatment process). Technical quality of the root filling seen on the post-operative radiographic was also assessed (quality of root filling). Pre-operative radiographs were used to determine the complexity of the cases treated. Healing was also assessed, using pre- and post-operative radiographs for comparison and clinical data collected at follow-up. Participant Patients completed OHIP-EOM questionnaires prior to commencement of root canal treatment, within 1 month of having completed root canal treatment and at follow-up. In all analyses incomplete data were excluded from the analysis.

6.1 Demographic Data for Participating Dentists

Five dentists (3 male and 2 female) with an age ranging from 27-44 years (mean 34.2 years, SD=7.08 years) participated in the course and contributed to these data. The mean time since qualifying was 10.2 years (SD=7.16 years, range 4-22 years). Four of the dentists worked in general practice settings and had not undertaken postgraduate training in endodontics. One worked within the Community Dental Services and had undertaken previous post-graduate training in endodontics.

6.2 Demographic Data for Participating Patients

These five dentists recruited 135 patients to the study. Forty-eight of the patients were male (36%), seventy-eight (58%) were female and nine (6%) did not state their gender. The age range of the patients is shown in Figure 22. The majority of the patients (56%) of the patients were aged between 25 and 44 years. Thirty percent were aged between 45 and 65 years, 10% were over 65 years and 4% were under 24 years. Seventy percent of patients were of white ethnic background and 45% were educated to university degree level or higher.

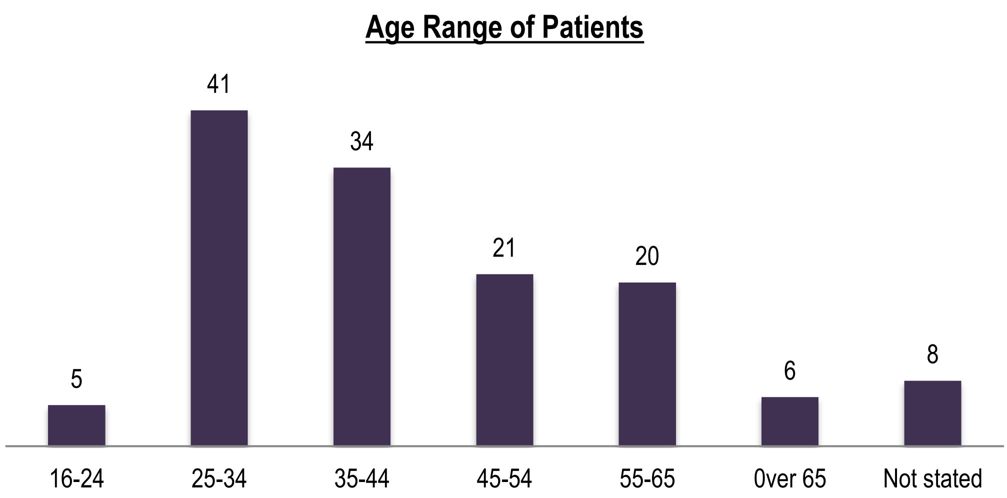

Figure 22: Age range of the patients who participated in this study

6.3 Complexity Level of Cases Treated

For this analysis, information reported in the logbooks maintained for each tooth and the preoperative radiographs of each tooth were used to gain an understanding of the complexity of teeth treated. Data to assess complexity were available for 113 patients. Complete data were available for 90 patients (67%) and the mean complexity score was 8.42 (SD=2.01, range 4-14). A score of between 6 and 15 was considered 'moderate complexity' (Al-Haboubi *et al.,* 2014). The majority of patients (58%, n=78) were seen for endodontic retreatment without further complicating factors. The remainder of teeth treated were for primary root canal treatment (8.9%, n=12), post removal (3%, n=4), open apices (1.5%, n=2), pre-operative procedural errors (2.2%, n=3) and there was missing data for the remainder (26%, n=36). The teeth treated were mainly lower posterior teeth (34%, n=46) and upper posterior teeth (31% n=42). The majority of teeth (64%, n=86) of teeth had multiple roots. The complicating factor seen most frequently was sclerosis (48%, n=65 patients). Resorption was present in 18 teeth (13%), root curvature >35' in 15 teeth (11%) and excessive root length (>25mm) in two teeth (1%).

6.4 Response Rate

Five of the eight dentists (63%) recruited patients to this aspect of the study. Two of the dentists worked within community dental services, one of whom was unable to recruit any patients to this study, as their patients were children and did not fulfil the inclusion criteria, as described in section 4.7. The third dentist failed to recruit any patients and the reason is unknown.

Of the 135 patients recruited to the study, treatment process data were available for 113 patients (84%) and post-operative radiographs for 108 patients (80%). Fifteen cases were completed in February/March 2011 (at the end of the course) and 98 cases were completed between April

2011 and August 2013. There were no differences in cases treated towards the end of the course and after the course was completed (Appendix X).

The initial response rate was good with pre-treatment questionnaires being returned by 130 patients (96%) and post-treatment questionnaires by 109 patients (81%). One hundred and six patients (79%) returned both pre- and post-treatment questionnaires. At follow-up (>12 months following completion of treatment), clinical and radiographic data were available for 33 patients (24%). Fifty-six patients (42%) returned the follow-up questionnaires. Fifty patients (37%) returned all three questionnaires, of which 35 were fully completed (26%). The proportion of patients recruited and providing all three questionnaires with OHIP-EOM sections fully completed, from each dentist is shown in Figure 23.

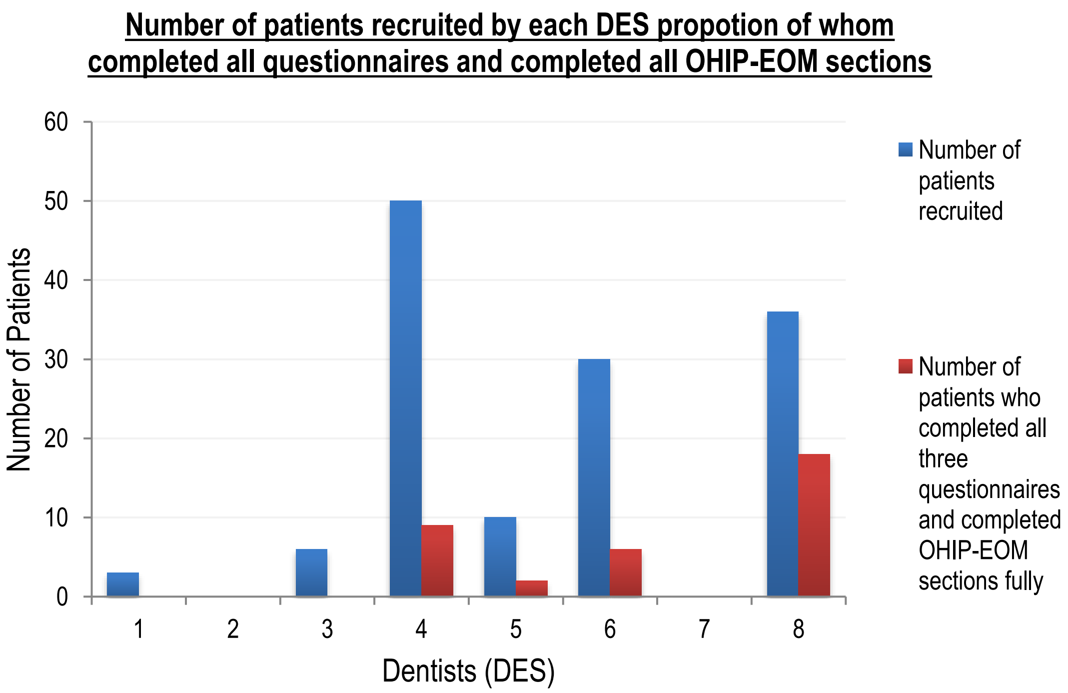

Figure 23: Numbers of patients recruited by each dentists and number of patients who returned all three questionnaires and fully completed the OHIP-EOM sections

6.5 Quality of Clinical Treatment Process

For determination of the Quality of Clinical Care provided, data from contemporaneous logbooks maintained by Participating Dentists were assessed in four domains, namely 1. use of rubber dam, 2. use of an apex locator to establish working length, 3. use of patency filing technique to maintain apical patency and 4. use of two irrigants (sodium hypochlorite and Ethylenediaminetetraacetic acid). These contributed to a total score that was computed for each patient (Table 40).

Seventy percent (n=96) of the Participant Patients received root canal treatment of high quality as discussed below. Rubber dam was used in 82% of patients. Only in one case was it recorded that rubber dam was not used. In the remainder of patients it was not stated if rubber dam was used or not. Apex locators were used in 82% patients and in the remainder of patients, it was not stated if apex locators were used. Patency filing was carried out in 73% patients and its' use was not stated in 25% of patients. In only 44% of the patients, a single irrigant (Sodium hypochlorite) was used. In 39% of the patients, both sodium hypochlorite and EDTA were used as irrigants. The used of an irrigant was not stated in 17%.

The overall Treatment Process Score was excellent for 33% of patients (n=52), good for 39% of patients (n=44) and fair for only 2% of patients (n=3). An overall score was not allocated for 27% patients where there were missing data making overall score calculation difficult. None were scored as poor. The mean Treatment Process Score where complete data were available (N=99, 73%) was 4.41 (N= 5 DES, SD=0.55, range 3-5) out of a possible score of 5.

Table 40: The proportion of teeth receiving each Treatment Process Score (data from contemporaneous logbooks maintained by the dentists) at Year 2 (n=8) and Post-training (n=5)

Cases	**Rubber Dam** (Y=1, N=0)		**Apex locator used** (Y=1, N=0)		**Patency filed** (Y=1, N=0)		**Cases**	**Irrigants used** (NaOCl + EDTA = 2, NaOCl=1, Anything else=0)		**Cases**	**Total Score** (0=poor, 5=good)	
	Yr 2	Post-training	Yr 2	Post-training	Yr 2	Post-training		Yr 2	Post-training		Yr 2	Post-training
N=	**72**	**112**	**75**	**111**	**74**	**101**	**N=**	**73**	**112**	**N=**	**72**	**99**
0	0	1	10	0	1	2	0	0	0	3	4	3
							1	49	60	4	51	52
1	72	111	65	111	73	99	2	24	52	5	17	44
Missing	3	23	0	24	1	34	Missing	2	23	Missing	3	36
Total Score	72	111	65	111	73	99	Total Score	97	164	Total Score	301	437
Proportion	1	0.99	0.87	1	0.99	0.98	Proportion	0.33	0.46	Mean	4.18	4.41
P value*	0.424		**0.00008**		0.749		**P value***	0.0672		**P value^**	**0.0160**	

*Z-test was used to compare proportions of the ideal scores and calculate the statistical significance of the difference from Year 2 to post-training
^Mann-Whitney U test was used to calculate the statistical significance of the difference in mean total scores from Year 2 to post-training (data were considered not to be normally distributed when tested). Z-ratio revealed statistical significance and the p-value is shown

In order to assess if skills were retained, the Treatment Process scores at the end of Year 2 were compared to that 'post-training'. When the score for the quality of the clinical treatment provided (Treatment Process Score) was compared to Year 2 for the entire cohort of dentists who underwent training (n=8), there was a statistically significant improvement in the use of Apex Locators ($p<0.05$), and in all other domains the standard was maintained (Table 41). Five of the Participant Dentists' recruited the additional patients for Part 2 of this study. When the Treatment Process Score was compared to Year 2 scores for the same five dentists at Year 2 (Table 41) statistically significant improvements were seen for the use of Apex Locators ($p=0.0$) and use of irrigants ($p=0.01$), whilst quality of treatment in the other domains were maintained post-training.

Table 41: The proportion of teeth receiving each Treatment Process Score (data from contemporaneous logbooks maintained by the dentists) at Year 2 (n=5) and Post-training (n=5)

Cases	**Rubber Dam** (Y=1, N=0)		**Apex locator used** (Y=1, N=0)		**Patency filed** (Y=1, N=0)		**Cases**	**Irrigants used** (NaOCl + EDTA = 2, NaOCl=1, Anything else=0)		**Cases**	**Total Score** (0=poor, 5=good)	
	Yr 2	Post-training	Yr 2	Post-training	Yr 2	Post-training		Yr 2	Post-training		Yr 2	Post-training
N=	**49**	**112**	**52**	**111**	**51**	**101**	**N=**	**50**	**112**	**N=**	**49**	**99**
0	0	1	0	0	0	2	0	0	0	3	0	3
							1	38	60	4	37	52
1	49	111	52	111	51	99	2	12	52	5	12	44
Missing	3	23	0	24	1	34	Missing	2	23	Missing	3	36
Total Score	49	111	52	111	51	99	Total Score	62	164	Total Score	208	437
Proportion	1	0.99	1	1	1	0.98	Proportion	0.24	0.46	Mean	4.24	4.41
P value*	0.51		**0.0**		0.31		**P value***	**0.01**		**P value^**	0.081	

*Z-test was used to compare proportions of the ideal scores and calculate the statistical significance of the difference from Year 2 to post-training

^Mann-Whitney U test was used to calculate the statistical significance of the difference in mean total scores from Year 2 to post-training (data were considered not to be normally distributed when tested). Z-ratio revealed statistical significance and the p-value is shown

6.6 Radiographic Quality of Root Canal Filling

Assessing the appearance of the root canal filling as seen on the post-operative radiograph provided an indication of the quality of the treatment. This included the scoring of four domains: the absence of procedural errors, the establishment of the correct working length (within 2mm of the apex), the achievement of the correct taper and shape achieved and the absence of voids within the root filling. The scores are shown in Table 42. Some radiographs were present but unusable due to the quality of the radiograph itself and therefore were recorded as such, effectively being treated as missing data in the analyses.

The score for the quality of the root filling as seen radiographically post-training for the five dentists' who recruited patients was compared to that at the end of Year 2 for the entire cohort of dentists who underwent training (n=8) in Table 43 and compared to data for the same five dentists at Year 2 in Table 43. A statistically significant difference was not found for any of the in either of the comparisons.

Table 42: The proportion of teeth receiving each Radiographic Outcome Score (from post-operative radiographs scored independently by two examiners) at Year 2 (n=8) and Post-training (n=5)

Cases	Procedural errors (Y=0, N=1)		Working length (Y=1, N=0)		Taper and Shape (Y=1, N=0)		Voids (Y=0, N=1)	
	Yr 2	Post-training	Yr 2	Post-training	Yr 2	Post-training	Yr 2	Post-training
N=	**64**	**103**	**64**	**103**	**64**	**103**	**64**	**103**
0	12	18	19	40	26	55	28	49
1	52	85	45	63	38	48	36	54
Unusable	1	6	1	6	1	6	1	6
Missing	10	26	10	26	10	26	10	26
Total Score	**52**	**85**	**45**	**63**	**38**	**48**	**36**	**54**
Proportions	0.81	0.83	0.70	0.61	0.59	0.47	0.56	0.52
P value*	0.834		0.230		0.107		0.631	

Cases	Overall (0=poor, 4=good)	
	Yr 2	Post-training
N=	**64**	**103**
0	2	9
1	10	16
2	9	18
3	29	42
4	14	18
Unusable	1	6
Missing	10	26
Total Score	**171**	**250**
Mean	2.67	2.43
P value^	0.234	

*Z-test was used to compare proportions of the ideal scores and calculate the statistical significance of the difference from Year 2 to post-training
^Mann-Whitney U test was used to calculate the statistical significance of the difference in mean total scores from Year 2 to post-training (data were considered not to be normally distributed when tested). Z-ratio revealed no statistical significance and the p-value is shown

Post-training, there were no procedural errors in 63% of patients. The correct working length was reached for 47% of patients. The ideal taper and shape was achieved for 36% of patients. A void free obturation was completed for 40% of patients. Radiographs were unavailable for 19% of patients and the radiographs were unusable for 4% of patients. For the patients where radiographs were available, the majority of patients (38%) received an overall root filling quality score of 3 out of a possible 4. Only 17% of patients received an overall score of four. The quality ratio (good/poor) as described by Molander *et al.,* (2007) and Dahlström *et al.,* (2011) was two. The mean score for the quality of the root filling as seen radiographically was 2.43 (N=5 DES, SD=1.20, range 0-4) out of a possible total score of four for the 103 patients (76%) with complete data.

Table 43: The proportion of teeth receiving each Radiographic Outcome Score (from post-operative radiographs scored independently by two examiners) at Year 2 (n=5) and Post-training (n=5)

Cases	Procedural errors (Y=0, N=1)		Working length (Y=1, N=0)		Taper and Shape (Y=1, N=0)		Voids (Y=0, N=1)	
	Yr 2	Post-training	Yr 2	Post-training	Yr 2	Post-training	Yr 2	Post-training
N=	**51**	**103**	**51**	**103**	**51**	**103**	**51**	**103**
0	10	18	14	40	21	55	23	49
1	41	85	37	63	30	48	28	54
Unusable	1	6	1	6	1	6	1	6
Missing	0	26	0	26	0	26	0	26
Total Score	**41**	**85**	**37**	**63**	**30**	**48**	**28**	**54**
Proportions	0.80	0.83	0.73	0.61	0.59	0.47	0.55	0.52
P value*	0.749		0.165		0.153		0.772	

Cases	Overall (0=poor, 4=good)	
	Yr 2	Post-training
N=	**51**	**103**
0	2	9
1	9	16
2	5	18
3	23	42
4	12	18
Unusable	1	6
Missing	0	26
Total Score	**136**	**250**
Mean	2.67	2.43
P value^	0.242	

*Z-test was used to compare proportions of the ideal scores and calculate the statistical significance of the difference from Year 2 to post-training
^Mann-Whitney U test was used to calculate the statistical significance of the difference in mean total scores from Year 2 to post-training (data were considered not to be normally distributed when tested). Z-ratio revealed no statistical significance and the p-value is shown

6.7 Assessment of Healing Process based on Radiographic Evidence

Evidence of radiographic healing was assessed using the post-operative radiographs and those taken at the follow-up appointment for comparison. It was not possible to ascertain the impact of additional training provided to the Participating Dentists on the outcome of treatment as radiographic evidence of healing of pre-training cases were not assessed; however as set out in this feasibility study, the possibility of collecting such data was demonstrated.

In the current study, post-operative and review radiographs were available for 31 patients (23%) and two of these were unusable. The fact that these radiographs were unavailable from the DES may indicate the negotiated contract, but is not to say that the referring dentist, as part of routine follow up, did not take these. Two dentists contributed the largest proportion of data for this analysis. Of the patients where radiographs were available, there was a reduction of size of lesion or no development of an apical area (healing or favourable outcome) for 19 patients (61%). No change in size of the apical area (uncertain outcome) was seen in 6 patients (19%). Increase in size or development of an area (failure or unfavourable outcome) was seen in four patients (13%). The mean score for healing as seen radiographically was 1.52 (N=3 DES, SD=0.74, range 0-2) out of a possible score of two, for the 29 patients (21%) with follow-up data. At the inception of the course the follow-up was not the responsibility of the DES and not funded by the service.

6.8 Assessment of Healing Process based on Clinical Evidence

Clinical healing was assessed using logbook data from follow-up appointments. Again, it was not possible to ascertain the impact of additional training provided to the Participating Dentists on the outcome of treatment as clinical healing of pre-training cases were not assessed; however, the possibility of collecting such data was demonstrated.

Follow-up data (including data for the presence of a coronal seal) were available for 34 patients (25.2%) and two dentists contributed the largest proportion of data for this analysis. Complete data were available for 21 patients (16%) of which 11 patients received an overall score of four (good), nine patients received a score of three and one patient scored zero (poor). There were two cases with clinical signs and symptoms of non-healing. Of 33 patients where data were available for the quality of the coronal restoration, nine patients (27.3%) were reported to have 'unsatisfactory' coronal restorations at the follow-up. Healing as seen clinically was recorded from logbook forms competed at the follow-up appointment. The mean score for healing as seen clinically (excluding data for the presence of a coronal seal) was 2.81 (n=2 DES, n=21 patients, SD=0.68, range 0-3) out of a possible total score of four. As outlined in Section 1.3, the follow-up and coronal restoration were not the responsibility of the DES and not funded by the service through commissioning arrangements.

6.9 Change in Quality of Life Scores (OHIP-EOM)

These data were collected via self-completed questionnaires and not all of the questionnaires returned were fully completed. The breakdown of the sections completed at each time point is shown in Table 44. The number of patients contributing to this data from each dentist is shown in Table 45.

Table 44: Number of OHIP-EOM questionnaires unfilled, partially and completely filled

	Pre-treatment questionnaire completely unfilled and returned	Pre-treatment OHIP section completely filled	Total	Post treatment questionnaire completely unfilled and returned	Post treatment OHIP section completely filled	Total	Follow-up questionnaire completely unfilled and returned	Follow-up OHIP section completely filled	Total
N	0	120	**130**	6	94	**109**	4	47	**56**
%	0	89	**96**	3	70	**81**	3	35	**42**
	10 (7.4%) were partially filled			**9 (6.6%) were partially filled**			**5 (3.7%) were partially filled**		

Table 45: Number of patients from each DES who completed each questionnaire

OHIP-EOM questionnaire	Dentist with Enhanced skills								Total
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
Pre-treatment questionnaire	3		5	42	10	29		31	120
Post treatment questionnaire			5	33	7	19		30	94
Follow-up questionnaire	1			13	2	8		23	47

From the questionnaires returned, the OHIP-EOM section was fully completed in 89% of the pre-treatment, 70% of the post-treatment and 35% of follow-up questionnaires. Seven additional questionnaires at follow-up were returned due to the addressee having moved. Time between completion of treatment and receipt of the follow-up questionnaire was 24.9months (SD=6.35 months, range 10.1 – 36.4 months) as the researcher depended on the DES. Data were available for 50 cases (for 6 cases the treatment completion date was missing and two patients did not complete any of the questionnaires). There was no difference in the demographics of those that returned completed questionnaires and those that returned incomplete or partially complete questionnaires (Table 46).

Table 46: Comparison of the demographics of those who completed all questionnaires (A) and those who completed some or none of the questionnaires (B)

Gender	A	B	Age	A	B	Ethnicity	A	B	Education	A	B
M	34%	36%	16-24	9%	2%	White	89%	63%	Do not have GCSEs or O-Levels	0%	1%
F	66%	55%	25-34	11%	37%	Black or Black British	2.5%	17%	GCSE or O-Levels	26%	21%
Not stated	0%	9%	35-44	31%	23%	Asian or Asian British	2.5%	3%	A levels	20%	7%
Total %	**100**	**100**	45-54	17%	15%	Mixed	6%	6%	Vocational qualifications	6%	13%
			55-65	29%	10%	Chinese or any other ethnic group	0%	3%	University degree or higher	46%	45%
			0ver 65	3%	5%	Not stated	0%	8%	Not stated	2%	13%
			Not stated	0%	8%	**Total %**	**100**	**100**	**Total %**	**100**	**100**
			Total %	**100**	**100**						

Mean summative score for all domains was 43.72 (95%CI 32.80-36.64) with scores ranging from 16-72 (Table 47). Post-treatment questionnaires were received from 109 patients (response rate of 80.7%), with 94 questionnaires fully completed. The mean summative score for all domains was 31.0 (95%CI 28.96-33.04) with scores ranging from 16-67. Review questionnaires were received from 56 patients (response rate of 41.5%), with forty-seven questionnaires fully completed. The mean summative score for all domains was 25.85 (95%CI 23.64, 28.06). As shown in Table 48, there was a mean change in total summative score for all domains, from pre-treatment to review of -6.14 (95%CI -8.68, -3.6). Thirty-five patients completed all three questionnaires with mean summative score for all domains being 33.2 (95%CI 30.31, 36.09) pre-treatment, 29.54 (95%CI 26.55, 32.53) post-treatment and 26.54 (95%CI 23.81, 29.27) at review. The mean change in summative score for all domains from pre-treatment to review was -6.66 (95%CI -9.76, -3.56).

As illustrated in Figure 24, the mean summative scores for all domains at various time points were not significantly different for all patients who completed at least one of the questionnaires when compared with the 35 patients who completed all three questionnaires. It was observed that those who gave low scores in the pre-treatment questionnaire also gave low scores on the post treatment questionnaire and in the follow-up questionnaires. There was a statistically significant difference in OHIP-EOM scores from pre-treatment to review, with OHIP-EOM scores being significantly lower at the follow-up appointment for those that participated in this research.

Table 47: Descriptive statistics of the questionnaires where all OHIP-EOM sections were completed and for those who completed all of the questionnaires (n=35)

	Questionnaires where all OHIP sections fully completed			Questionnaires where all OHIP sections fully completed for pre tx questionnaire & post treatment questionnaire		Questionnaires where all OHIP sections fully completed for pre tx questionnaire & follow-up questionnaire		Questionnaires where all OHIP sections fully completed for post tx questionnaire & follow-up questionnaire		35 cases where all questionnaires and OHIP sections fully completed		
	Pre Tx	**Post Tx**	**Follow-up**	**Pre Tx**	**Post Tx**	**Pre Tx**	**Follow-up**	**Post Tx**	**Follow-up**	**Pre Tx**	**Post Tx**	**Follow-up**
N =	120	94	47	84	84	43	43	38	38	35	35	35
% =	89	70	35	62	62	32	32	28	28	26	26	26
Total score	4166	2914	1215	2885	2608	1400	1136	1109	988	1162	1034	929
Mean	34.72	31.00	25.85	34.35	31.05	32.56	26.42	29.18	26.00	33.2	29.54	26.54
SD	10.74	10.11	7.74	9.79	10.08	8.44	7.76	8.77	8.21	8.73	9.01	8.23
SE	0.980	1.043	1.129	1.068	1.100	1.287	1.183	1.423	1.332	1.4756	1.5230	1.3911
95% CI lower	32.80	28.96	23.64	32.26	28.89	30.04	24.10	26.39	23.39	30.31	26.55	23.81
95% CI upper	36.64	33.04	28.06	36.44	33.21	35.08	28.74	31.97	28.61	36.09	32.53	29.27
Median	33	28	24.5	33	28	32	25	27	24	32	27	24
Range	16-72	16-67	16-55	16-72	16-67	16-52	16-55	16-49	16-55	16-52	16-49	16-55

Tx = Treatment

Table 48: Change in OHIP-EOM scores from one time period to another where all OHIP-EOM sections were completed and for those who completed all of the questionnaires (n=35)

	Change from pre to post-treatment		**Change from post-treatment to follow-up**		**Change from preTx to follow-up**	
N	84	35	38	35	43	35
%	62	26	28	26	32	26
Total score change	-277.0	-128.00	-121.0	-105.00	-264.0	-233.00
Mean	-3.30	-3.66	-3.18	-3.00	-6.14	-6.66
SD	7.835	8.6	8.421	8.63	8.487	9.03
SE	0.855	1.454	1.366	1.460	1.294	1.526
95% CI lower limit	-4.98	-6.51	-5.86	-5.86	-8.68	-9.76
95% CI upper limit	-1.62	-0.81	-0.50	-0.14	-3.60	-3.56
Median	-2	-3	-2	-2	-6	-6
Range	+13 to -28	+13 to -25	+22 to -21	+22 to -21	+14 to -26	+14 to -26

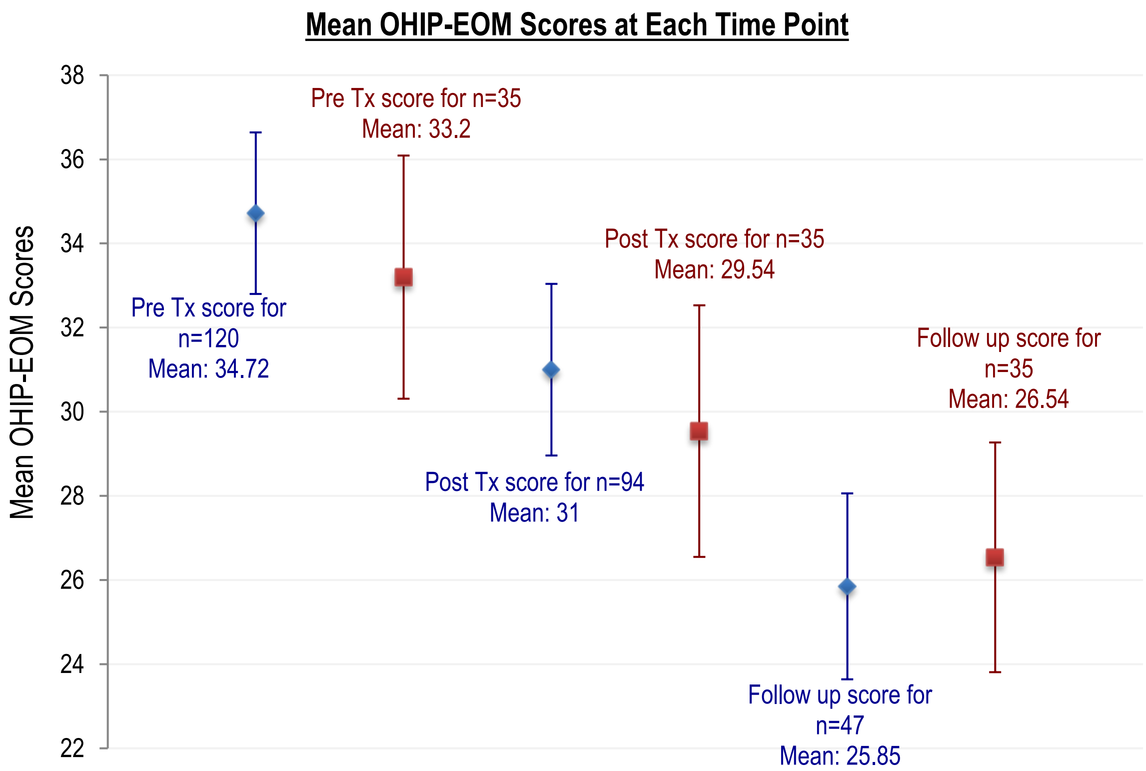

Figure 24: Mean OHIP-EOM scores (pre-treatment, post-treatment and follow-up)

Tx = treatment

Mean scores at each time point were calculated for the separate domains of oral health (Table 11, Section 2.5.5.5). The mean scores for each domain for all of the patients who completed at least one component of one of the questionnaires is shown in Table 49. There were significant differences seen in the mean score for the domains of 'Physical Pain', 'Physical Disability', and 'Physiological Discomfort' from pre-treatment to follow-up.

The mean scores for patients who completed the relevant questions for each domain at all three time points are shown in Table 50. A significant reduction in the OHIP-EOM scores for the domain of 'Physical Disability' and 'Physiological Discomfort' were seen from pre-treatment to follow-up. Significant differences were not seen in any of the other five domains.

Table 49: Descriptive statistics for domains of oral health where relevant OHIP-EOM sections were completed at least at one of the time points

	Functional Limitation			Physical Pain			Physical Disability			Physiological discomfort			Physiological Disability			Social Disability			Handicap		
	Pre-tx	Post-tx	Follow-up	Pre-tx	Post-tx	Follow-up	Pre-tx	Post-tx	Follow-up	Pre-tx	Post-tx	Follow-up	Pre-tx	Post-tx	Follow-up	Pre-tx	Post-tx	Follow-up	Pre-tx	Post-tx	Follow-up
N=	128	101	51	123	96	52	128	99	52	128	100	52	126	99	52	128	100	52	128	99	48
% =	94.8	74.8	37.8	91.1	71.1	38.5	94.8	73.3	38.5	94.8	74.1	38.5	93.3	73.3	38.5	94.8	74.1	38.5	94.8	73.3	35.6
Mean	5.96	5.45	5.49	10.37	9.29	8.17	6.29	5.8	4.54	2.86	2.41	2.17	4.02	3.75	3.38	1.56	1.42	1.21	3.37	2.99	2.38
SD	1.92	1.69	1.67	3.45	3.17	3.71	2.54	2.64	2.36	1.11	1.1	1.15	2.02	2	1.87	1	0.84	0.7	1.82	1.55	0.79
95% CI lower	5.62	5.11	5.02	9.75	8.65	7.14	5.85	5.28	3.88	2.66	2.19	1.85	3.66	3.35	2.86	1.39	1.25	1.02	2.05	2.68	2.15
95% CI upper	6.29	5.78	5.96	10.98	9.93	9.21	6.73	6.34	5.2	3.05	2.63	2.49	4.37	4.15	3.91	1.74	1.59	1.41	2.69	3.3	2.6
Range	3-14	3-12	3-12	4-20	4-17	4-20	3-15	3-15	3-15	1-5	1-5	1-5	2-10	2-10	2-10	1-5	1-5	1-5	2-10	2-10	2-5

Tx = treatment

Table 50: Descriptive statistics for domains of oral health where relevant OHIP-EOM sections were completed at all of the time points

	Functional Limitation			Physical Pain			Physical Disability			Physiological discomfort			Physiological Disability			Social Disability			Handicap		
	Pre-tx	Post-tx	Follow-up	Pre-tx	Post-tx	Follow-up	Pre-tx	Post-tx	Follow-up	Pre-tx	Post-tx	Follow-up	Pre-tx	Post-tx	Follow-up	Pre-tx	Post-tx	Follow-up	Pre-tx	Post-tx	Follow-up
N=	42	42	42	39	39	39	40	40	40	41	41	41	40	40	40	41	41	41	38	38	38
% =	31.1	31.1	31.1	28.9	28.9	28.9	29.6	29.6	29.6	30.4	30.4	30.4	29.6	29.6	29.6	30.4	30.4	30.4	28.1	28.1	28.1
Mean	6.05	5.52	5.5	10.41	8.92	8.08	6.45	5.65	4.53	2.91	2.34	2.15	3.98	3.78	3.45	1.39	1.49	1.27	2.92	2.87	2.47
SD	2.08	1.95	1.76	3.58	3.43	3.87	2.37	2.88	2.53	1.18	1.11	1.2	1.98	2.04	1.88	0.97	1	0.78	1.14	1.26	0.86
95% CI lower	5.4	4.91	4.95	9.25	7.81	6.82	5.69	4.73	3.72	2.53	1.99	1.77	3.34	3.12	2.85	1.08	1.17	1.02	2.54	2.46	2.19
95% CI upper	6.7	6.13	6.05	11.57	10.03	9.33	7.21	6.57	5.33	3.27	2.69	2.52	4.61	4.43	4.05	1.7	1.8	1.51	3.3	3.28	2.76
Range	3-11	3-12	3-12	4-20	4-17	4-20	3-11	3-15	3-15	1-5	1-5	1-5	2-10	2-10	2-10	1-5	1-5	1-5	2-6	2-6	2 -5

Tx = treatment

6.10 Assessment of Quality of Treatment by Dentists with Enhanced Skill (post-training)

The quality of endodontics provided by these participating dentists with enhanced skills in endodontics post completion of training was analysed using the mean total Process and Outcomes Score as shown in Table 26. When measuring change in Skills (Part 1), only Process Quality was scored. In patients recruited post-training, Process Quality and Treatment Outcome Scores were calculated.

The total Process Quality Score (excluding the presence of a satisfactory coronal seal) post-training was 6.81 (n=5 DES, n=88 patients, SD=1.34, range 3-9) out of a total possible score of 9. When the mean total Process Quality Score for the five dentists' that recruited patients to the second part of this study was compared to the Process Quality Score for the entire cohort of dentists and also specifically for these five dentists, there was no statistically significant difference in the scores at the end of Year 2 compared to post-training (Figure 25).

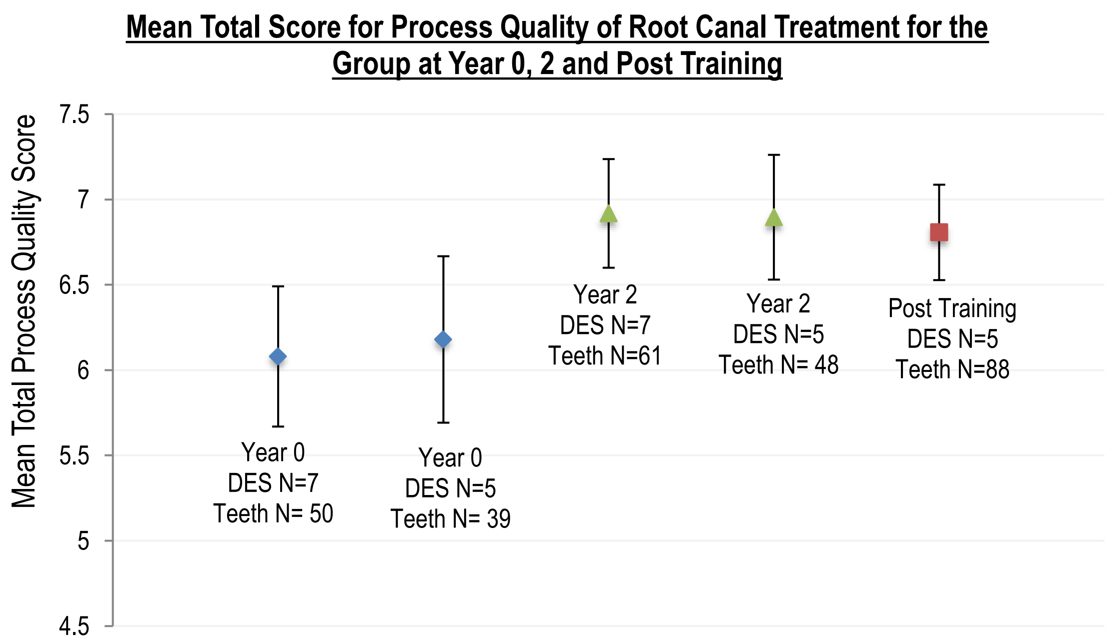

Figure 25: Mean total process quality score comparison with Year 0, Year 2 and post-training

When the mean total Outcome Score (excluding the presence of a satisfactory coronal seal) was analysed, the mean score was 4.44 (n=2 DES, n=18 patients, SD=0.78, range 3-5) out of a total possible Outcome Score of 5.

When the total Process Score and that for Outcome (including the presence of a satisfactory coronal seal) were combined for a measure of overall quality, the mean score was 11.72 (n=2 DES, n=18 patients, SD=0.34, range 9-14) out of a total possible Quality Score of 15. That excluding the presence of a coronal seal was 11.11 (n=2 DES, n=18 patients, SD=0.36, range 9-13) out of a total possible Quality Score of 14. It was not possible to compare the overall quality during the training course and after the training course as healing was not assessed during the course.

6.11 Endodontic Treatment Provided by Dentists with Enhanced Skills: Summary of Outcomes

This feasibility study showed that it is possible to engage some dentists and patients in research, and use the measurement tools developed within this study for capturing data and scoring quality of root canal treatment, in general dental practice, even when no longer part of a training programme. However, there were delays in receiving patient data from the dentists and not all participated and indeed were able to participate.

It has been demonstrated that the data collected in this study permitted calculation of Process and Outcome quality scores for root canal treatment. It is also possible to collect quality of life data. The findings from this section suggest that among participating dentists the quality of root canal treatment can be maintained after completion of training. There was a significant improvement in the quality of life from pre-treatment to follow-up for those that returned the questionnaires. The following chapters describe findings for the second objective exploring the patients' perspective of the service they received, the dentists' perception of the trainings and the estimated cost of the pilot initiative.

Chapter 7: Results (Part 3): Patient View of the Service

In this Chapter patients' perception of the service is presented (Objective 2). This is an important objective of the current study, as patients are the end users of the service. Patient perceptions were determined using a self-completed set of questionnaires given to participating patients at key time periods (prior to, during and after root canal treatment).

7.1 Questionnaires

The same questionnaires used to ascertain OHIP-EOM scores were used with additional questions (Appendices S, T and U). First was prior to commencement of endodontic treatment and the second was after completion of the treatment programme. Third was after a period of approximately 1 year after the second questionnaire. Main topics covered in the questionnaires were; overall patient view of the service, willingness to retain or lose a natural tooth, cost, and Information provided and/or received. A section of the first questionnaire gathered information about the perception of the service to which they were being referred. This section also ascertained the fees paid and the patients view on saving their tooth at any financial cost. The second questionnaire asked a series of questions regarding the experience of having treatment within this service. The third questionnaire (at more than 12months after completion of the root canal filling) did not ask questions relating to the service. Not all questionnaires were returned and not all sections were completed. Percentages stated in this Chapter have been calculated in relation to the total number of patients to the study (n=135).

7.2 Patients Views on Being Referred to this Service

The patients were asked if they received a clear explanation of why they were being referred to this service. This question was completed in 129 of the returned questionnaires. The majority, 127 patients (94.1%), stated that they received a clear explanation of the service they were referred to. Only two patients (1.5%) stated that they failed to receive a clear explanation of why they were referred to this service. That this explanation may have come from their own dentist who may have a variable understanding of the service depending on the information distributed by the service to the referring dentists. One hundred and twenty five patients answered the question asking who their own dentist was. Almost half of the patients (n=65, 48.1%) stated that their own dentist was working in another practice referred them to this root canal service, 49 patients (36.3%) stated that their own dentist was working within the same practice as this root canal service, and 11 patients (8.1%) stated that it was their usual dentist who was also providing this root canal service. When asked how satisfied patients were about being referred to another dentists for this service, 123 patients answered the question, with 35.6 % (n=48) very happy, 50.4 % (n=68) happy, 3.7 % (n= 5) unhappy and 1.5% (n=2) very unhappy.

7.3 Patient Views on Fee Payments for Using This Service

Patients were asked if they usually pay for the NHS dental treatment, and 129 patients provided an answer to this question. The majority (n=89, 65.9%) paid a fee, 36 patients (26.7%) did not pay a fee and four patients (3%) were not sure if they paid a fee for NHS dental treatment. When asked if they had already paid their dentists for this course of treatment, 127 patients answered this question. Thirty-five patients had already paid (25.9%), 76 patients (56.3%) had not yet paid and 16 patients (11.9%) were unsure if they had paid. Interestingly, only 44 patients answered the question about how much they had already paid for their treatment. When asked if the cost of their treatment was clear, 51 patients answered the question. The majority of patients (n=34, 25.2%) said yes, ten patients (7.4%) said no and seven patients (5.2%) were not sure. When asked to state their agreement with the phrase ‘I would do anything to save a tooth, no matter how much it costs’, 123 patients answered the question. The majority of patients were agreed (n=65, 48.1%) or strongly agreed (n=33, 24.4%). Twenty-three patients (17%) disagreed and 2 patients (1.5%) strongly disagreed with the statement. No statistically significant differences were found between the OHIP-EOM scores (Table 51) or change in OHIP-EOM scores (Table 52) for those that agreed or disagreed with this statement.

Table 51: OHIP-EOM scores at each time point compared to patients' agreement with the phrase ''I would do anything to save a tooth, no matter how much it costs'

'I would do anything to save a tooth, no matter how much it costs'	Pre-treatment					Post-treatment					Follow-up				
	OHIP-EOM score	N	SD	Lower 95%CI	Upper 95%CI	OHIP-EOM score	N	SD	Lower 95%CI	Upper 95%CI	OHIP-EOM score	N	SD	Lower 95%CI	Upper 95%CI
Strongly agree	34.5	30	11.34	30.27	38.73	29.96	26	9.5	26.12	33.8	27.57	7	10.37	17.98	37.17
Agree	34.56	61	11.45	31.63	37.49	32.7	46	10.79	29.49	35.9	27.33	21	8.73	23.36	31.31
Disagree	35.39	23	9.6	31.24	39.54	27.75	12	8.86	22.12	33.38	23.57	14	4.13	21.19	25.95
Strongly disagree	32.5	2	6.36	-24.68	89.68	33	2	8.49	-43.24	109.24	25.5	2	3.54	-6.27	57.27

Table 52: Change in OHIP-EOM scores compared to patients' agreement with the phrase ''I would do anything to save a tooth, no matter how much it costs'

'I would do anything to save a tooth, no matter how much it costs'	Change from Post-treatment to Follow-up					Change from Pre to Post-treatment					Change from Pre-treatment to Follow-up				
	OHIP-EOM score	N	SD	Lower 95%CI	Upper 95%CI	OHIP-EOM score	N	SD	Lower 95%CI	Upper 95%CI	OHIP-EOM score	N	SD	Lower 95%CI	Upper 95%CI
Strongly agree	0.29	7	12.62	-11.34	11.96	-4.04	23	6.89	-7.02	-1.06	-3.43	7	12.73	-15.2	8.34
Agree	-1.88	17	6.85	-5.4	1.64	-1.98	43	7.81	-4.38	0.43	-4.83	18	7.74	-8.68	-0.98
Disagree	-5.56	9	8.5	-12.09	0.98	-5.17	12	8.81	-10.76	0.43	-8.79	14	7.88	-13.33	-4.24
Strongly disagree	-7.5	2	4.95	-51.97	36.97	0.5	2	2.12	-18.56	19.56	-7	2	2.83	-32.41	18.41

7.4 Patient Views of the Service Received

Participant patients were asked a series of questions regarding the service they received (Table 53). One hundred and two patients answered questions regarding the overall satisfaction with the service. The majority of patients said they were very satisfied (n=87, 64.4%), eleven patients (8.1%) said they were satisfied; none said they were dissatisfied and four patients said they were very dissatisfied (3%). In this study it was not possible to understand the reasons why these patients were dissatisfied with the service. All four of these patients did not return the follow up questionnaire and there was no follow up data available for these patients, although the data suggests the root canal treatment was completed for all four patients. The change in OHIP-EOM scores from pre- to post-treatment was zero, -3, -13 and -21 points for these four patients.

Table 53: Questions asked to ascertain patient views about the service they received

	N=	Very poor	Poor	Good	Very good
How thoroughly did the dentist ask about your condition?	102	0	1	18	83
How well did the dentist listen to what you had to say?	102	0	1	16	85
How well did the dentist explain your treatment?	102	0	1	11	90
How well did the dentist explain what you should expect to feel after the treatment?	102	0	1	19	82
How much did the dentist involve you in decisions?	100	0	0	23	77
How well did the dentist put you at ease during your treatment?	102	0	1	9	92
The amount of time the dentist spent with you.	101	0	0	15	86
Confidence and trust in the dentist.	101	0	1	6	94
How did you feel about the cleanliness within the surgery?	102	0	0	15	87
The dentist was thorough in doing the procedure.	102	1	0	11	86
The dentist was gentle when they worked on me.	102	1	1	20	80
I was satisfied with what the dentist did.	102	1	0	12	89
The dentist seemed to know what they were doing during the procedure.	102	1	0	6	95

The majority of patients affirmed that they would definitely use the service again (n=92, 68.1%) and ten patients (7.4%) stated that they would probably use this service again. None reported that they would avoid this service in the future. The majority related that they would definitely recommend this service to friends and family (n=91, 67.4%), ten patients (7.4%) conveyed that they would probably recommend this service and one (0.7%) said they would probably not recommend this service to friends and family. None stated that they would definitely not recommend this service to friends and family.

7.5 Patient Views on Their Own Health

In all three questionnaires given to patients, they were asked to comment on their own general health. In the pre-treatment questionnaire and the post treatment questionnaire, they were asked about the presence of other problems or conditions (in the mouth) apart from the one they were being treated for.

7.5.1 Perceived General Health

Prior to treatment the majority of patients stated that their general health was good (n=44, 32.6%), very good (n=29, 21.5%) or excellent (n=23, 17%). Twenty-seven patients (20%) stated that their general health was fair and five patients (3.7%) stated that their general health was poor. At completion of treatment, majority of patients stated that their general health was good (n=32, 23.7%), very good (n=25, 18.5%) or excellent (n=22, 16.3%). Twenty patients (14.8%) stated that their general health was fair and two patients (1.5%) stated that their general health was poor. At follow-up, the majority of patients stated that their general health was good (n=24, 17.8%), excellent (n=14, 10.4%) or very good (n=8, 5.9%). Four patients (3%) stated that their general health was fair and one patient (0.7%) stated that their general health was poor. There were no statistical differences between the OHIP-EOM scores for those that stated their general health as excellent, very good, good, fair or poor (Table 54).

7.5.2 Perceived Other Oral Health Issues

Before and after treatment the patients were asked if they were suffering from any other problems or conditions (in the mouth) apart from the one for which they were having treatment. Prior to treatment the majority of patients stated that they did not suffer from any other problems associated with their mouth (n=81, 60%), thirty-nine patients (28.9%) stated that they did suffer from other oral health issues and nine patients (6.7%) stated that they were not sure if there were other problems in their mouth. Following completion of treatment the majority of patients stated that they did not suffer from any other problems associated with their mouth (n=64, 47.4%), twenty-eight patients (20.7%) stated that they did suffer from other oral health issues and ten patients (7.4%) stated they were not sure if there were other problems in their mouth. There were no statistical differences between the OHIP-EOM scores for those that stated the presence or absence of other conditions within the mouth (Table 55).

7.5.3 Perceived Change to Their Oral Health after Treatment

Following completion of treatment the majority of patients stated that their oral health improved a lot (n=56, 41.5%), improved a little (n=20, 14.8%) or stayed the same (n=16, 11.9%). None of the patients stated that their oral health worsened. At follow-up the majority of patients stated that their oral health improved a lot (n=30, 22.2%), and a minority stated that it improved a little (n=11, 8.1%) or stayed the same (n=7, 5.2%). Three patients (2.2%) stated that their oral health worsened a little and one patient (0.7%) stated that their oral health worsened a lot following treatment. There was no statistically significant difference in the change in OHIP-EOM scores from pre-treatment to post-treatment for those that stated that their oral health improved or stayed the same following completion of the treatment in their post treatment questionnaire (Table 56). There was no statistically significant difference in the change in OHIP-EOM scores from pre-treatment to review for those that stated that their oral health improved, stayed the same or worsened following treatment in their review questionnaire (Table 57).

Table 54: OHIP-EOM scores at each time point in comparison to the patients' perception of their own general health

Perception of general health	Pre-treatment					Post-treatment					Follow-up				
	OHIP-EOM score	N	SD	Lower 95%CI	Upper 95%CI	OHIP-EOM score	N	SD	Lower 95%CI	Upper 95%CI	OHIP-EOM score	N	SD	Lower 95%CI	Upper 95%CI
Excellent	32.67	18	7.56	28.89	36.44	29.2	20	7.61	25.64	32.76		0			
Very good	32.63	27	8.15	29.41	35.85	26.58	24	7.59	23.38	29.79	23.42	12	5.9	19.67	27.17
Good	34.76	42	11.49	31.18	38.34	29.21	29	8.35	26.03	32.38	20.75	8	4.4	17.07	24.43
Fair	36.31	26	9.58	32.44	40.18	38.88	17	8.34	34.59	43.17	29.23	22	8.73	25.35	33.1
Poor	46.6	5	21.92	19.33	73.81	38.5	2	28.99	-221.98	298.98	25.25	4	5.74	16.12	34.38

Table 55: OHIP-EOM scores at each time point in comparison to the patients' perception of the presence of other oral conditions being present in the mouth at the time

Other oral conditions present	Pre-treatment					Post-treatment				
	OHIP-EOM score	N	SD	Lower 95%CI	Upper 95%CI	OHIP-EOM score	N	SD	Lower 95%CI	Upper 95%CI
Yes	39.86	37	12.82	35.59	44.14	36.2	25	10.18	32	40.4
No	32.03	72	8.61	30	34.05	27.97	59	8.32	25.8	30.13
Not sure	36.11	9	8.62	29.48	42.74	31.5	8	7.6	25.15	37.85

Table 56: Change in OHIP-EOM scores from pre- to post-treatment in comparison to patients' perceived change in their oral health

Perceived change in oral health	Change in OHIPEOM Pre- to Post-treatment				
	OHIPEOM score	N	SD	Lower 95%CI	Upper 95%CI
Improved a lot	-3.98	45	8.27	-6.46	-1.49
Improved a little	-3.21	19	8.75	-7.43	-1.0
Stayed the same	-1.43	14	6.47	-5.16	2.3
Worsened a little		0			
Worsened a lot		0			

Table 57: Change in OHIP-EOM scores from post-treatment to follow-up in comparison to patients' perceived change in their oral health

Perceived change in oral health	Change in OHIPEOM Pre-treatment to Follow-up				
	OHIPEOM score	N	SD	Lower 95%CI	Upper 95%CI
Improved a lot	-8.09	23	8.76	-11.88	-4.3
Improved a little	-2.4	10	7.04	-7.44	2.64
Stayed the same	-7.43	7	5.86	-12.84	-2.01
Worsened a little	-0.67	3	13.32	-33.75	32.41
Worsened a lot		0			

7.6 Perceived Status of the Tooth after Treatment

In the post treatment questionnaire patients were asked about if their tooth improved after treatment. Following completion of treatment the majority of patients stated that their tooth improved a lot (n=71, 52.6%), improved a little (n=13, 9.6%) or stayed the same (n=8, 5.9%). None of the patients stated that their tooth worsened after treatment. There was statistically significant difference in OHIP-EOM scores (Table 58) or change in OHIP-EOM scores (Table 59) for patients that stated whether their tooth improved or stayed the same after treatment.

Table 58: OHIP-EOM scores at each time point in comparison to the patients' perceived improvement in the tooth treated

Perceived improvement in tooth treated	Pre-treatment					Post-treatment					Follow-up				
	OHIPEOM score	N	SD	Lower 95%CI	Upper 95%CI	OHIPEOM score	N	SD	Lower 95%CI	Upper 95%CI	OHIPEOM score	N	SD	Lower 95%CI	Upper 95%CI
Improved a lot	33.06	64	8.6	30.92	35.21	29.32	66	8.21	27.3	31.34	26.45	22	7.26	23.24	29.67
Improved a little	39.92	12	12.64	31.89	47.95	35.17	12	12.03	27.52	42.81	28	9	11.23	19.37	36.63
Stayed the same	32	7	9.47	23.24	40.76	29.88	8	13.49	18.6	41.15	22.4	5	7.23	13.42	31.38
Worsened a little		0					0					0			
Worsened a lot		0					0					0			

Table 59: Change in OHIP-EOM scores in comparison to the patients' perceived improvement in the tooth treated

Perceived improvement in tooth treated	Change from Post-treatment to Follow-up					Change from Pre to Post-treatment					Change from Pre-treatment to Follow-up				
	OHIPEOM score	N	SD	Lower 95%CI	Upper 95%CI	OHIPEOM score	N	SD	Lower 95%CI	Upper 95%CI	OHIPEOM score	N	SD	Lower 95%CI	Upper 95%CI
Improved a lot	-2	22	9.01	-6	2	-3.8	60	8.43	-5.98	-1.62	-6	21	10.47	-10.77	-1.23
Improved a little	-5	9	8.17	-11.28	1.28	-1.82	11	6.57	-6.23	2.6	-7.38	8	6.59	-12.88	-1.87
Stayed the same	-1.8	5	6.38	-9.72	6.12	-1.86	7	7.2	-8.51	4.8	-5.25	4	7.14	-16.6	6.1
Worsened a little		0					0					0			
Worsened a lot		0					0					0			

7.7 Retention of the Treated Tooth at Follow-Up

In the review questionnaire patients were asked if their tooth was still present and if so, what filling had been placed on the tooth. At follow-up, a quarter of the patients stated that their tooth was still present (n=48, 25.6%). Four patients (3%) stated that they longer had the tooth that was treated. These were not the same four patients who were very dissatisfied with the service (Section 7.4). Three of the patients had a score of 3 out of a possible 4 for the appearance of the root filling as seen radiographically. There was no clinical or radiographic data for the fourth patient. Of the patients with a tooth present, the majority (n=28, 20.7%) stated they had crowns or onlays placed on the tooth, twelve patients were not sure of how the tooth was restored (n=12, 8.9%). Five patients (3.7%) stated that the tooth was restored with a new tooth coloured filling; two patients (1.5%) stated that the tooth was restored with a new silver filling and one patient (0.7%) stated that the tooth still had the temporary filling in situ. There was no statistically significant difference in OHIP-EOM scores at any time point (Table 60) or change in OHIP-EOM scores (Table 61) for patients that stated whether their tooth was still present at follow-up.

Table 60: OHIP-EOM scores at each time point in comparison to the patients' knowledge of the tooth treated still being present at follow-up

Is tooth still present?	Pre-treatment					Post-treatment					Follow-up				
	OHIP-EOM score	N	SD	Lower 95%CI	Upper 95%CI	OHIP-EOM score	N	SD	Lower 95%CI	Upper 95%CI	OHIP-EOM score	N	SD	Lower 95%CI	Upper 95%CI
Yes	33.95	44	10.88	30.65	37.26	29.27	37	10.47	25.78	32.76	25.63	43	7.85	23.21	28.04
No	34.75	4	9.91	18.98	50.52	38.33	3	8.15	18.1	58.57	28.25	3	6.9	17.27	39.23
Not sure		0					0					0			

Table 61: Change in OHIP-EOM scores in comparison to the patients' knowledge of the tooth treated still being present at follow-up

Is tooth still present?	Change from Post Treatment to Follow-up					Change from Pre to Post-treatment					Change from Pre-treatment to Follow-up				
	OHIPEOM score	N	SD	Lower 95%CI	Upper 95%CI	OHIPEOM score	N	SD	Lower 95%CI	Upper 95%CI	OHIPEOM score	N	SD	Lower 95%CI	Upper 95%CI
Yes	-2.86	35	8.32	-5.72	0	-4.15	34	8.36	-7.06	-1.23	-6.1	39	8.79	-8.95	-3.25
No	-7	3	10.54	-33.17	19.17	0	3	9.54	-23.7	23.7	-6.5	4	5.45	-15.17	2.17
Not sure		0					0					0			

7.8 Summary of Patients' Views of the Service

Data obtained in this pilot study demonstrated that it was possible to follow-up patients in a primary care setting via questionnaires submitted through their primary care dentists and received at a different academic setting. By this process, it was possible to document and analyse patient views on the quality of service provided, their level of satisfaction (or lack of it), costs and fee payments, issue of referrals and patient's own health status according to their own judgement.

Most patients were referred to the service by a dentist not involved in the DES scheme, and were happy to have been referred. Many patients stated that their oral health and the tooth improved a lot following treatment from this service. A large proportion of those who returned the review questionnaire stated that they have retained the tooth treated and the most common restoration on the tooth was a crown or onlay. Most patients were motivated to save their tooth at any financial cost. This section of the study suggests that an overwhelming majority of patients were happy with the service they received, would use the service again if needed in the future and would recommend the service to others.

The following section reports on the dentists' perception of this service and their perceived benefits to them, their patients and the wider NHS.

Chapter 8: Results (Part 4): Dentists View of the Training Initiative

Participating dentist views and perceptions were obtained using self-completed questionnaires, information collected after completion of the training initiative, but prior to receiving their final examination results. This constituted the second Objective of the study, the Trainee perspective of the training initiative.

8.1 Participants

All eight participants completing the training course provided feedback using a questionnaire designed for this purpose. Of these, six participant dentists answered all of the questions and two participants omitted four questions in total. One participant failed to provide an answer to three of the questions, and another participant failed to provide an answer to one question. All omitted questions were related to ideas for improving the course and endodontic services within general dental practice.

Participant dentists' prior experience in endodontics was not uniform. This ranged from those having had no prior formal training since their undergraduate training (n=2), included those who reported gaining significant experience in general practice (n=3), to others who reported attending continuing professional development courses (n=2) and even gained a Diploma in endodontics (n=1). Their motivation for enrolling in this course included encouragement from the PCT, payment for this course by the PCT and provision of paid study leave by the PCT.

8.2 Course Content and Delivery

All participant dentists reported an overall positive experience in different themes such as (a) organisation of the training course, (b) provision of appropriate reading material (c) learning culture and (d) the learning environment. These are summarised in Table 62. Organisation of the course included associated NHS arrangements and the system of triaging of patients to be treated as part of the learning experience of the course. The course was considered inspirational and enjoyable, fostering a supportive, helpful and inclusive learning environment. Developments suggested involved greater levels of contact with teachers from the outset of the course with emphasis on gaining practical skills, more sessions under supervision, short and targeted training, greater discussion of cases and shorter seminars. The participants observed the different learning styles of the group and perceived the need for and benefit of students receiving more individualised feedback and support.

> *"I believe that the rotary instruments and warm vertical/backfill technique should have been introduced in earlier modules"* (**P1Q4**).
>
> *"I think more contact time at the start would have been better, also doing more on root preparation and apical gauging and techniques at the start would have increased our clinical standard more quickly"* **(P2Q2).**
>
> *"A little bit more one to one support initially in some of the practical sessions…"* **(P3Q6)**.
>
> *"Maybe short focused seminars would be more productive"* **(P3Q4)**.
>
> *"To improve have some patient sessions under supervision"* **(P5Q4)**.
>
> *"More discussion on the completed cases in practice. Where we went wrong and what could have been improved. We did discuss cases but now and then, was never compulsory"* **(P5Q6)**.
>
> *"My colleagues and I consisted of 9 individuals with widely different levels of training experience and skills in dentistry. We also have varying personalities and personal commitments […] fortunately most of the teachers on the course understood this and were very encouraging. Perhaps a little more individual feedback would have been useful throughout the course"* **(P6Q6)**.

The course was delivered in tandem with the NHS provision of general dental services with NHS time and funding allocated for enhancing skills in endodontics for these practitioners. This was recognised and appreciated as an integral part of training.

> *'Without such an arrangement it would be impossible to dedicate the time necessary to develop the skills learned at the course and it would be extremely unlikely for a NHS dental practice to absorb the extra cost it does involve'* **(P1Q10)**

Table 62: Themes that emerged from the participant views of the course and the NHS arrangements supporting the course

Themes	Examples
Organisation	*"Excelled in providing a balance between theoretical and practical teaching for a busy GDP"*'**(P8Q2)** *"It was a perfect course for a dentist who did not want to or could not go to full time training due to family reasons. It was perfect combination of formal training and general practice experience"* **(P2Q5)** *"The course teachers were very supportive in providing the appropriate reading materials and literature prior to the study days. This proved invaluable throughout the course"* **(P6Q5)** *"The programme was very well organised"* **(P1Q3)**.
Culture	*"Very well organised. Culture created by course tutors was very good - professional yet friendly and inclusive"* **(P4Q3)** *"It was hard work but enjoyable"* **(P3Q2)** *"The support from the teachers was excellent"* **(P1Q5)**
Developmental	*"A little bit more one to one support initially in some of the practical sessions to address individual problems"* **(P3Q6)** *"More discussion (needed) on the completed cases in practice. Where we went wrong and what could have been improved"* **(P5Q6)** *"I believe that the rotary instruments and warm vertical/backfill technique should have been introduced in earlier modules"* **(P1Q4)** *"I think more contact time at the start would have been better, also doing more on root preparation and apical gauging and techniques at the start would have increased our clinical standard more quickly"* **(P2Q2)** *"Maybe short focused seminars would be more productive"* **(P3Q4)**

8.3 Impact on Participants, Their Patients and Their Organisation

As shown in Table 63, the perceived effect(s) of the training course on participant dentists was not limited to endodontics but covered related areas of practice such as improved confidence, gaining skills, knowledge and understanding, improved clinical experience, and changes in wider practise.

Table 63: Examples of the participant perceptions of the impact of the course on themselves, their patients and their organisation

Perceived impact of the course on themselves	Perceived impact of the course on their patients and on their organisation
'…Ignited an interest in dentistry and has spurred me to improve myself and continue to educate myself. I am now seeking an evidence based approach to all aspects of my dental treatment' **(P7Q2)** *"The course in DwSI in endodontics took me to a totally different level of dentistry. It changed the way I practiced in general. It did mainly inspire me to use an evidence-based approach to most things I do"* **(P1Q2)** *"…Decision-making, treatment planning and technical skills have improved"* **(P5Q8)** *"…I can carry out more complex endodontics with greater confidence. It has also given me a deeper knowledge and understanding of many aspects of restorative dentistry"* **(P6Q2)** *"Understanding, diagnosis, consistency of results"* **(P2Q9)** *"Definitely without a doubt the basic principles are the same but a completely new approach to achieving these principles"* **(P3Q8)** *"My technical procedure is totally different to what I was doing before"* **(P5Q9)**	*"So many teeth have been saved"* **(P6Q7)** *"The in depth knowledge and skill acquired during the course has enabled me to provide an improved standard of care to my patients"* **(P3Q2)** *"It is the best value for money, as most of the cases treated by us [did] not [therefore] require specialist treatment"* **(P1Q14)** *"Patients have got such a good standard of root canal treatment for the same NHS charges or for free, which they would not have dreamt of getting"* **(P5Q7)** *"Absolutely, the biggest surprise in this course was the fact that most aspects of the course could be practiced in general dentistry"* **(P1Q7)**

There was support and appreciation for time and resources allocated to improving skills in primary care. There were no perceived negative impacts of the course; however, challenging suggestions for improving the course delivery as previously illustrated were apparent. For some the impact on themselves was very significant as illustrated below:

> *"This has been a career changing experience for me. I have exited this course with a new outlook on dentistry and I am much happier with my skills and understanding as a whole"* **(P7 free text comments section at the end of questionnaire)**

The perceived impact of the course on the participant's organisation (NHS dental practice) were better or predictable clinical outcomes, access to NHS endodontic treatment, improved care, improved outcomes, value for money and empathy were also described in the transcripts. Positive feedback from patients was described in relation to the service, thoroughness of care, time spent and explanations of the treatment. The course was perceived as relevant to general dental practice.

> *"The most relevant course I could ever attend. In my PCT patients have benefitted within 6 months of the start of the course"* **(P6Q7)**

The perceived positive aspects of NHS arrangements included resources, triaging and referral systems. The perceived negative factors were lack of organisation, remuneration, understanding and clarity.

> *"An understanding that it is a labour intensive treatment… That unless they have long term funding for enough patients to be treated by a DwSI, the training expense may prove to be not very financially viable to the NHS"* **(P8Q12)**
>
> *"Clear agreement and commitments to arrangement by both PCT and DwSI {dentists with extended skills}"* **(P7Q12)**

The transition of these skills into primary care and implementation of change was viewed to be dependent mainly on remuneration and production of appropriate care pathways. Local agreements and national policy on remuneration in primary dental care were perceived as important issues to be addressed. There was a call for coordinated care pathways and time for training within new commissioning arrangements. There was widespread appreciation for the PCTs who supported the initiative, however better organisation and communication were highlighted as areas for improvement. There was an obvious intention to use the skills learned to provide improved care and high quality endodontics within the NHS; however, there was uncertainty and concerns as to whether the service would be commissioned in the future. Participants voiced concerns that the resources used to provide this pilot programme would be wasted, by all stakeholders in the initiative, if the service was to no longer be purchased. The participants did not state that they would be looking to provide this service in the private sector.

> *"My PCT having invested in me for 2yrs is now suggesting they have limited finances to support me after April 2011. This makes very little financial sense"* **(P6Q12)**
>
> *"Despite seeing the benefits of the programme to the patients and the service the PCTs commitment to me after April 2011 is unknown as yet"* **(P6Q11)**

Wider views included the importance in value for money and quality of care deserved by NHS patients and recommended better undergraduate training in endodontics. Many suggestions for commissioners included better understanding of moderate complexity endodontic care services (time and single use equipment required), better triaging services, written clarification, agreements and commitments to financial arrangements between commissioners and providers. The local factors affecting change in practice may be related to participants adopting techniques. The effect of equipment is not described in the transcripts possibly as a result of all equipment being provided by PCTs to carry out treatment in line with current best practice.

The perceived barriers to providing endodontics generally in primary care within the NHS were described as remuneration, time, skills/training, cost of providing the service or 'motivation' / 'incentive', accountability and quality assessment.

> *"For the 'average' NHS practitioner: funding, lack of accountability i.e. motivation and incentives"* **(P4Q15)**

"The funding to root canal treatment is the biggest barrier. The young dentists are not at all motivated as they are not paid or very well for it. Disposable files are expensive and that does not help the practice principal. This is inculcating a culture in general practice that doing root canal is a waste of time and money" **(P5Q15)**

"For a general dentist, skill, magnification, undergraduate training, material cost, equipment available at the practice, use of rubber dam, remuneration" **(P2Q15)**

Overall participants stated training and remuneration important to facilitating the delivery of high quality endodontic treatment in NHS practices (Figure 26). Having this programme may have overcome some of the barriers such as *'resources (such as time equipment etc.), skills and knowledge'* ***(P3Q15)***; however did not address other barriers such as *'Incentive, motivation,'* **(P4Q16)** and *'Better undergraduate training'* **(P8Q16)**.

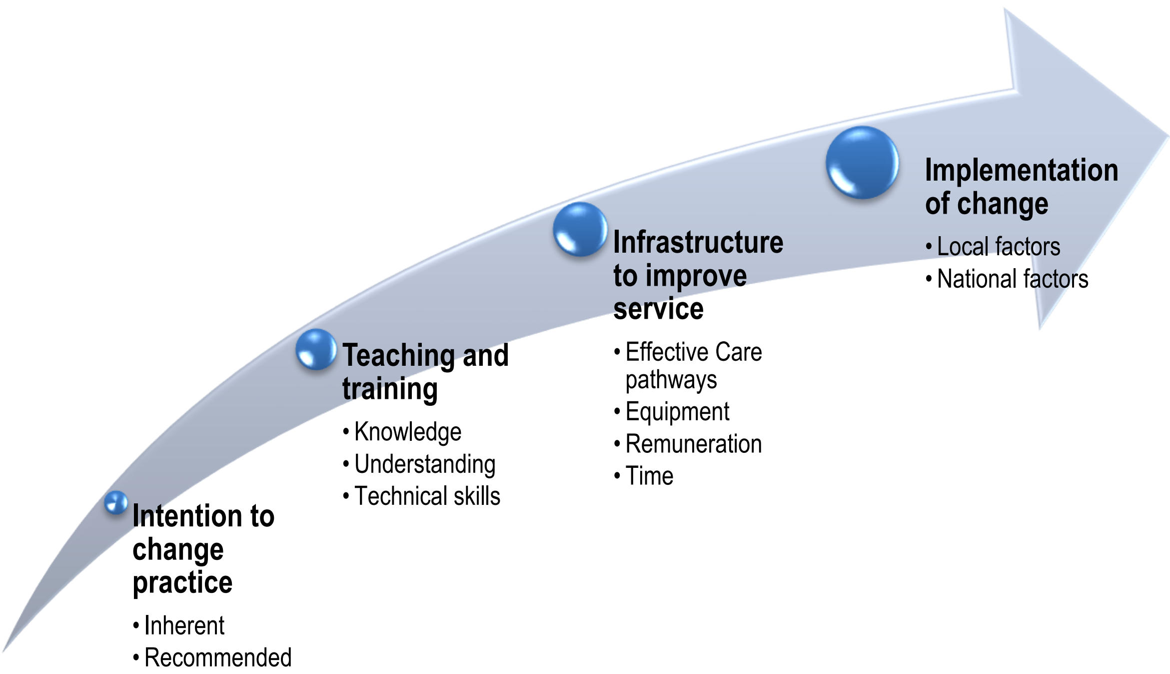

Figure 26: Potential barriers and barriers to implementing change in practice as identified by the participants of the course

8.4 Summary of Dentists' Views on the Training Initiative

The ability to capture participant views of the impact of additional training on themselves, their organisation and wider healthcare following training has been established. The findings suggest adult learning theories, when implemented achieve self-perceived behavioural change. This learner feedback provides invaluable insight into achieving behavioural change in primary care general dental practitioners for future training and development of services. The final section of this chapter shows the potential cost of providing this service which has been revealed in the previous sections to advance and maintain skills, improve oral health and are valued by both dentists and patients involved in the resultant services.

Chapter 9: Results (Part 5): Estimated Cost of the Training Initiative

In this Chapter, the third and final objective of this study is met, and estimated costs of training are presented for the model of training assessed in this study, in comparison currently accepted postgraduate dental mono-specialist training models in the United Kingdom.

9.1 Estimated Cost of Training

A basic requirement for a new and an alternative model for training dental post-graduates is that it should be cost effective, in addition to being of better quality in terms of service and participant satisfaction. The training course described in this study consisted of 168 hours of didactic teaching and hands-on workshops delivered over 24months including seminars, lectures and hands-on training in simulation laboratory. As such, it was difficult to accurately estimate the costs involved because of the multiplicity of factors involved. The London Deanery and PCTs absorbed the cost of the training including purchasing of some of the equipment. It is estimated that each PCT provided on average £25,000 per person towards this training. Materials were provided for the teaching days by QED (Quality Endodontic Distributors Ltd, Peterborough, UK). The estimated costs are shown in Table 64.

The total cost of training is estimated at £664,400. This is a total of £83,050 per dentist for both years including equipment. The number of teeth treated, as part of this training was approximately 1600, which equates to a total cost of £415.25 per tooth. If these teeth were to be treated by a specialist in endodontics in primary care the cost is likely to be approximately £500-£600 per tooth. If these teeth were to be treated in secondary care the cost is likely to be approximately £464 per tooth (Table 65), however, it is unlikely that the majority of these cases will be accepted for treatment due to the level of complexity. For the same cost as the entire course, if the treatment was provided by a speciality or in a hospital setting, between 1,074 and 1,338 teeth could have been treated.

It is difficult to compare the cost of training in this course with other courses due to its novelty. No other courses pay for the completion of cases during the course but in a practice setting as part of the course. If, instead of the training provided by the London Deanery, these eight dentists were enrolled in a part time two year Masters (MSc) programme in endodontics, the cost would be £191,200. This would not include the purchasing of equipment for the practice at which the dentist will eventually work, nor would it include the provision of endodontics in primary care for 1600 teeth. If the same model is used and in addition to the 2-year MSc the same numbers of teeth were to be treated, the same costs of equipment and fee per treatment would apply (Table 64).

Table 64: Total costs associated with training in a simulated environment

Description of cost	Cost (£)	Method of calculation	Comparative cost of Monospecialty training in endodontics*
Hire of premises for teaching	£36,000	Cost for 24 days with clinical skills lab and seminar room	**Fees paid by dentist: £23900 x 8 = £191,200**
Teachers fees Supporting costs - visits to practices/direct supervision Examination costs - external examiner fees	£44,400	£600-800 per teacher per day for 2 teachers per day: (800x2)x24 = £38400 £1500 per teacher for writing modules: 1500x4 = £6000 Exam held in seminar room (one of the 24 days: no added cost)	MSc 1yr FT = £24,410 MSc 2yr PT = £11,950 per year (£23900 for 2yrs) MClinDent 2yr FT = £24,410 per year MClinDent 4yr PT = £18,850 per year (FT = 5days per week) (PT = 5days first 8 weeks then 3days)
Equipment costs	£200,000	£25K by 1 PCT (x8 DwSIs): 25000x8 = £200,000	£200,000 if the same equipment is bought
Number of teeth treated during course	£384,000	£240 per tooth (100x2) x 8 = 1600 (100 per year by each dentist)	If the same number of teeth are funded for treatment at the same fee £240 per tooth (1600x240 = £384,000)
Total cost of course	**£664,400**		**£775,200**

* Eastman Dental Institute fees for Endodontology 2015/16. http://www.ucl.ac.uk/current-students/money/2015-2016_fees/2015-16_postgrad_taught

Table 65: The cost of providing this treatment in a secondary care setting

Hospital Appointments	Cost	Tariff per procedure (i.e. per appointment)^
New Patient Assessment	£107 - £153	£107 - £153
Endodontic Procedure	£228 - £440	£114 - £220 Likely to need 2 appointments (114x2=228 and 220x2=440)
Total	£335 - £593 (average cost £464)	

^NHS England Outpatient Procedure Tariffs 2015/16. https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0ahUKEwiBsMXk3-DLAhUL7BQKHR85CdAQFgghMAE&url=https%3A%2F%2Fwww.england.nhs.uk%2Fwp-content%2Fuploads%2F2015%2F03%2F2015-16-eto-spreadsheet.xlsx&usg=AFQjCNHr4y_QdTX6KyU96-knpRLOAHcyLQ&bvm=bv.117868183,d.d24

9.2 Estimated Time Spent Improving Skills

As shown in Table 66, the participant dentists spent a minimum of 18,072 hours and a maximum of 58,096 hours on improving their technical skills during the training course. There was no statistically significant difference in the number of appointments taken to complete treatment (Figure 27) before and after training for those dentists who participated in the prospective part of this research (n=5). As shown in Figure 28, there was a statistically significant difference in the number of appointments taken for completion of treatment both at Year 0 and Year 2 for those that did recruit patients for the second part of the study (N=5) and those that did not (N=2). One dentist failed to provide data for teeth/patients treated during and post-training. The increased number of appointments taken for completion of the treatment may be related to the complexity of the patients being treated (not necessarily the complexity of the tooth itself).

Table 66: Hours spent improving technical skills in simulated and general practice settings

Endodontic training Blocks and teeth in simulated setting	24 days (one session on hands-on technique equivalent to 3-4 hours per day)	Min 3 x 24 = 72 hours Max 4 x 24 = 96 hours
100 cases per year	Minimum 90 minutes or possibly maximum 3x90 minutes per case	Min 90 x 200 = 18,000 hours Max 290 x 200 = 58,000 hours
Total hours spent improving technical skills		Min of hours = 18,072 hours Max of hours = 58,096 hours

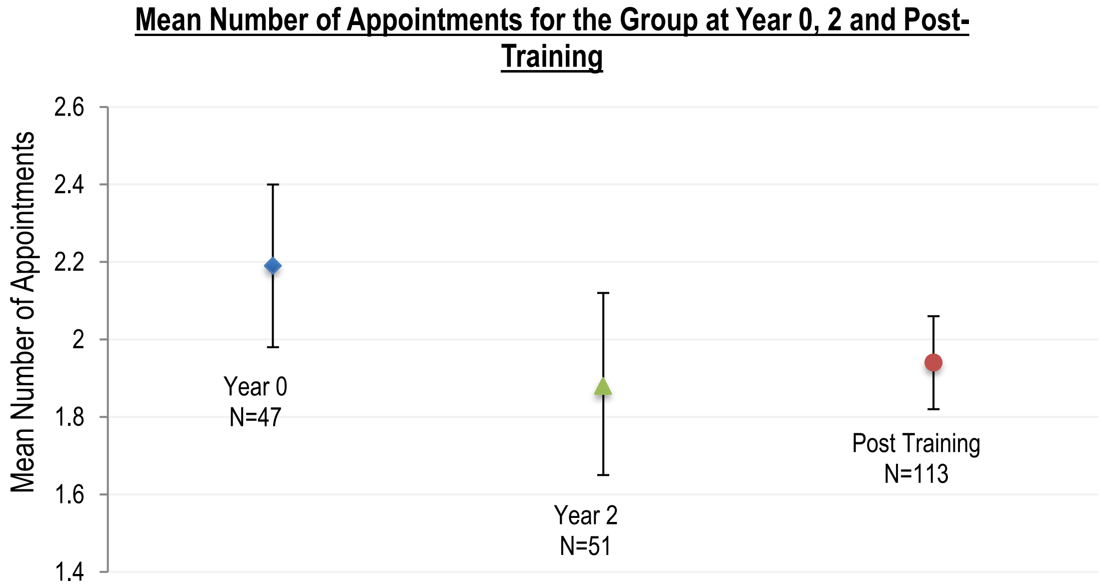

Figure 27: Mean number of appointments with 95% Confidence Intervals for those dentists who participated in recruiting patients for the second part of this research (N=5)

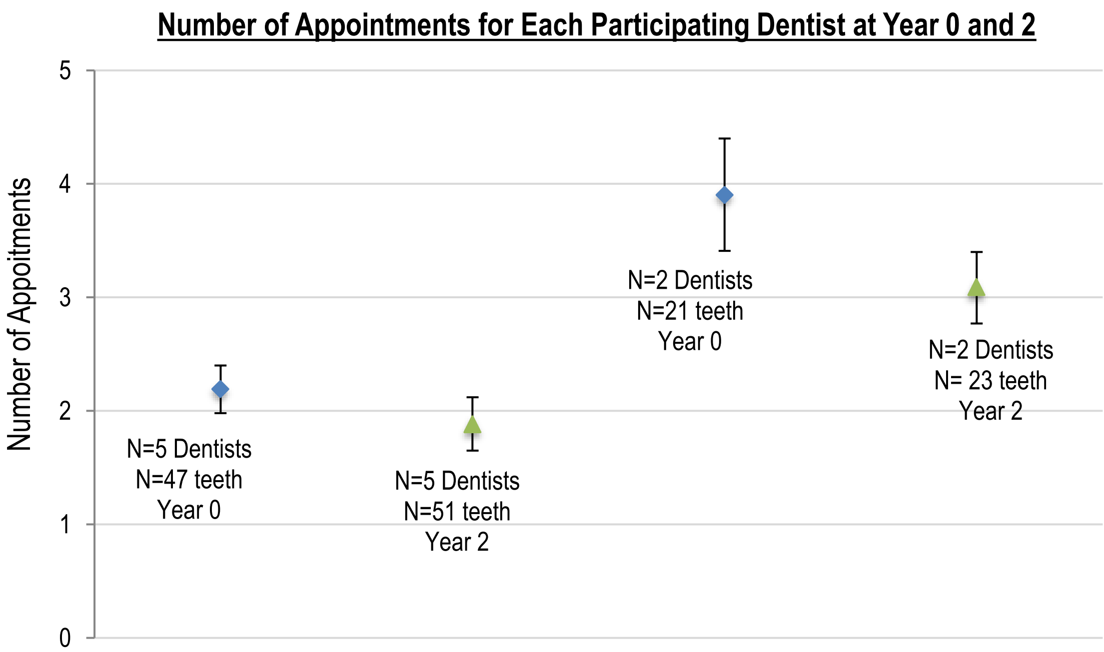

Figure 28: The Mean Number of Appointments Taken to Complete Treatment at Year 0 and Year 2 by dentists who recruited patients (N=5) and those that did not (N=3)

9.3 Summary of Cost and Time Estimates

The estimated cost of training was smaller than providing the same service intermingled with training using already available courses. The number of hours spent improving skills is significant; however only so, if such training involves the treatment of this volume of cases commissioned in this initiative. Those that engaged in the research also appeared to have completed cases over a smaller number of appointments during the training phase.

Chapter 10: Discussion

This feasibility study demonstrated that it was possible to conduct research in primary general dental care settings to explore the quality of treatment and in turn the outcome of additional training. It used specially developed measurement tools to capture outcome related data and to quantify quality of root canal treatment provided in primary care. Learning from the feasibility component of this study should inform quality measures for root canal treatment in everyday practice and measurement of outcomes of training in endodontics.

Preliminary findings from this study suggested that a training programme combining didactic teaching in a simulated laboratory and concomitant experience working within their own practices can be successful in changing practice. Those course participants who engaged in the research demonstrated adoption of techniques taught, and achieved a high level of clinical and patient related outcomes as a result of having completed this course. Additionally, the course participants stated that they gained more than technical abilities alone during this course and changed practice outside of root canal treatment. There was a positive impact on professionalism of dentists and quality of life of patients. This alternative model was seen favourably by dentists and can result in maintenance of the skills learned after completion of training with positive patient related outcomes.

The financial cost of the course was estimated at approximately £83,050 per dentist for both years when 1600 teeth were saved. There is therefore evidence for stakeholders to invest in this design of additional training for general dentists, thereby improving the quality of primary dental care in England. The everyday tools formalised for capturing data and measuring quality have been validated and show reliability in assessing quality of Process and Outcome, if appropriate training is administered regularly. These findings present an insight into an area within dentistry, which is not yet explored within the literature.

10.1 Context of Study

This training programme was developed when the Primary Care Trusts still existed and were responsible for ensuring that the citizens in their respective areas had access to NHS dental care including endodontic treatment. Following the introduction of the new dental contract for primary care in 2006, there was a change in referral patterns and an increase in the number of cases being referred to secondary care, often due to the changes in remuneration for time consuming treatment. Additionally, due to changes in undergraduate curricula and possibly the lack of suitable patients, fewer graduates were qualifying with confidence to manage technically challenging dentistry in such areas as oral surgery, endodontics and prosthodontics. Due to emphasis on prevention, periodontal care should have been better managed; however remuneration still did not reward prevention. The introduction of the 18-week pathway for patients in secondary care, significant pressures were present to avoid developing and maintaining waiting lists for treatment within secondary care. In response capacity was optimised, however this was not sufficient to meet the demand. As a result, more stringent criteria were developed for the acceptance of patients for treatment within secondary care, limiting to high complexity cases for strategically important teeth and those patients requiring multidisciplinary care. These pressures are ever increasing, especially in this time of austerity. The combination of these factors resulted in a group of patients whose treatment needs do not qualify them for treatment within a hospital setting because the treatment was not complicated enough or was in a non-strategic tooth. Yet these patients could also not ascertain the treatment with their own dentist as the dentist stated that they either never had or no longer had the confidence and skills to carry out this treatment. Hence, the development of the term dentistry of 'moderate complexity' (Al-Haboubi *et al.,* 2014), the demands for which were not met in neither primary nor secondary NHS dental care. Patients complained to the then Primary Care Trusts and secondary care practitioners complained to the then Deaneries for the shortage in access to dentists with the appropriate skills to meet this demand.

In 2009, a training programme was established to build expertise in the primary care setting and enable general dentists to develop enhanced skills in a distinct field whilst still continuing to work as a generalist for part of their time. There was very limited evidence in the literature regarding the feasibility of providing such training, and measuring the effect of such training on the dentist's skills and the outcome of endodontics within primary care, especially within the UK. This study uses the measurement tools developed to capture data from this pilot initiative in order to inform future randomised controlled studies in this area.

This initiative and study took place at a time of great flux within the NHS system and much uncertainty was present regarding the future models of care. During the course of this study the NHS changed from a devolved system of PCTs to a national unified system. Initially, there were the uncertainties associated with the future of Primary Care Trusts and their ability to purchase endodontic treatment from Dentists with Enhanced Skills in Endodontics. If these financial limitations were to have arisen, there was potential for a negative impact on the possibility of reaching the desired sample size. Since then the NHS has developed and the current direction of change is to move towards a tiered system of care, where the complexity of the treatment needs is matched with the skills of the practitioner. Therefore there is a place for tools to score complexity of cases and tools to measure quality in terms of treatment outcome in order to also measure skills of clinicians in a comparative manner. In future studies, the long-term plans for training and research should be integrated and secured prior to commencement in order that resources are not wasted.

10.2 Strengths and Limitations of the Study

In this feasibility study, data collected were randomised and blinded by one investigator who was also involved in the teaching of the course. The primary investigator (SE) was involved in writing and teaching several modules of the course. The strength of this was the ability to intimately understand the delivery of the course and engage with the DES to collaborate on this research. The weakness in this was the potential bias relating to DES involvement in the research, the inability to carry out in depth interviews to understand the participant views of the training and a potential bias in scoring endodontic training blocks and radiographs. These have been overcome to some degree using anonymised written self-completed questionnaires and significant training and calibration in scoring radiographs. All data were blinded for stage of training and operator and randomised prior to scoring. Future studies should ensure that those independent of teaching the course and those independent of assessing outcomes carry out this process. Elimination of bias in patient allocation to treatment and clinician should be considered in future. Similarly, elimination of bias in the reporting of treatment process data should be overcome with the adoption of routine recording of all aspects of the treatment process.

There is bias due to clustering of data, as a small number of (self-selected) participants with varying training and experience were enrolled in the training. These limited numbers of dentists were assessed without a control group. However, there was no scope to introduce a control group hence; the dentists were assessed longitudinally, against themselves at different time points. Further self-selection has occurred as some of the participants engaged in the research process far more than the others.

The course was developed and established prior to the conception of this study, and there were time pressures to commence training due to the lack of patient access to endodontic treatment of moderate complexity in London. Therefore it was not possible to collect data prior to the establishment of the training course. Significant challenges were present in obtaining research and development approval from seven PCTs, St George’s University Hospitals NHS Foundation Trust and Kings College London as well as an ethical approval from the South East London Research Ethics Committee Proportionate Review scheme. The time associated with development of the study protocol and delays in gaining ethical approval meant difficulties in influencing the design of the course to capture data that would benefit the study. Therefore the development of the processes of the teaching course was not influenced by the research. The participants (both teachers and students) were aware that such research will be taking place and therefore there is the possibility of an element of observational bias.

There was a great reliance on the dentists participating in this course to enrol and to provide data for this study; including collecting data as part of routine treatment provision as well as collecting and forwarding information to the research team in a timely manner. They also needed to maintain the quality of the information entered into their logbook, which formed a significant portion of this study. Ideally ten percent of the patients who consented to take part should have had the logbook summary compared with the clinical notes (although again there would be reliance on accurate note keeping). However, it was not possible to check a large percentage of clinical notes for accuracy in comparison to the logbook forms due to distance and time constraints. It was noted in the few sets of clinical notes, which were checked that a copy of the logbook form was being used as part of the clinical record to record the treatment carried out. There was also significant dependence on the DES recruiting patients for the second component of this study. Maintaining complete trust in the participants supplying accurate information also contributed to the development of and sustenance of a good working relationship with the participants, as without heavy reliance on the participants providing sufficient data it would not have been possible to complete this study.

This is a 'real world' feasibility study where little additional research support was given. It reflects a true view of what is possible in terms of research in primary NHS dental practices. Throughout this discussion, particular limitations have been noted which highlight the difficulties of carrying out high quality dental research in NHS primary care, especially in a highly transient population base such as in London. Retention and engagement in research may be difficult without motivating factors, and possible incentives. However, this should be considered carefully and in accordance with Health Research Authority (HRA) guidance on Payments and Incentives in Research (HRA, 2014). The ramifications of incentives and the ethical dilemmas of using incentives must be considered (Grant & Sugarman, 2004; Singer & Couper, 2008). It was challenging to engage the dentists to contribute to this study, as the incentive was limited to having data to present to commissioners regarding the quality of the treatment provided. In order to secure dentists in research in the future, participation may need to be simple and incorporated easily into the working day. Ideally the data collection should be digital and routine as part of clinical record keeping. As radiographs form part of the clinical record, can therefore be easily included. Incentives for full participation could be drawn into contractual agreements possibly with remuneration for the treatment attached to the completion of the electronic data. Reminders to complete the electronic records and linking this to remuneration may improve compliance with routine data collection (Cheung *et al.,* 2012). The following section discusses the study findings. No more than descriptive analysis and simple statistics were required as the results were clear.

10.3 Learning from this Feasibility Study

Feasibility studies are crucial to the success of future trials to ensure that all processes planned work smoothly and allow better understanding of the patient and healthcare professionals views (Lancaster, 2015). The most important component of feasibility studies is the learning for the future trial, which is outlined in the following sections.

10.3.1 Recruitment and Retention of Participants

10.3.1.1 Dentists

Recruitment of dentists to the study was part of the contractual agreements made when enrolling in training. It was not clear how failing to engage in research would impact individual dentists, but considered a goodwill gesture for the resources invested in providing additional training. The Primary Investigator used the relationships built with these dentists during training to encourage engagement. This was possible during the course but more difficult following completion of it. Those that remained involved in the process did have enhanced fee contracts for providing root canal treatment as a DES within the NHS. Whether those who failed to cooperate had the same is unknown. For some there was a need to collect this data to ensure future NHS contracts where a logbook of cases was required for accreditation (Department Of Health/FGDP UK, 2006a). One dentist did not provide any cases for analysis for this research and the reason is not clear. Those dentists who engaged with the research process post-training, supplied electronic data that they were maintaining as part of their own on-going logbook, used to negotiate contracts with commissioners.

Recruitment, if based on voluntary participation may be variable, which may be representative of general dental practitioners, of whom some engage in research in exchange for training free of charge and there may be national differences such as a need to demonstrate research involvement to fulfil licence requirements (Mjör, 2007). Perceived barriers of North American medical practitioners to participate in practice based research have been reported as ‘lack of time, inadequate training in research methods, lack of collaborators and support staff, institutional review board hurdles, and community distrust of research’ when questioned via focus groups and questionnaires (Bakken *et al.,* 2009). It has been suggested that dentists who are expected to participate in research should be given formal training in the principles of undertaking research in primary care prior to practice-based research, be given ‘a certain amount of ownership’ such that a collaborative role is reinforced rather than purely a technical role, and be helped to identify the adaptations needed to 'incorporate research activities into their daily practice' (DeRouen *et al.,* 2008). Practice based or 'real world' research should not interfere with the daily routines of practice and should reimburse clinicians for the extra time required to 'obtain patients' consent and record the data required for the research' (Mjör, 2007). Dentists recruited to the current study were trained in establishing patient consent and completing the necessary clinical record keeping, which is part of routine clinical practice, however, were not specifically trained in the principles of or reimbursed. This is a consideration that may help recruitment and retention of clinicians in future studies. As practice based research lacks standardisation, a larger number of clinicians would need to be recruited to compensate (Mjör, 2007).

This study showed that not all general dental practitioners would engage with research. It is not known how representative the group of dentists involved in this study are of the general population of dentists in England. Previous reports have suggested that recruiting general dental practitioners into clinical trials within primary care settings is not well understood (Crawford, 2005). This study has proven that it is possible to engage both dentists and patients in primary care research and that some can be engaged over years of follow-up. In this particular study, there was little tangible gain for the dentists themselves in engaging in research and no agreed remuneration for follow-up, which is a known incentive (Tickle *et al.,* 2011). For the dentists enrolled in this training programme, between two (25%) and seven (87.5%) dentists of the eight dentists participated in providing patient related data, when the various components of the study were considered separately. One dentist failed to provide patient data for all components of the study, without any explanation. Two of the dentists worked within community dental services and their patients were unable to meet the inclusion criteria. For future studies, it may be worthwhile gaining ethical approval to include children having root canal treatment who are able to consent to taking part in research, as two of the dentists in this study mainly treated children and yet were unable to recruit many patients to the study. Department of Health research within primary care has shown low compliance (27% for patient surveys, 24% for staff and 34% for dentist surveys for those involved in dental pilots) in previous reports where dental practices have been involved in pilots (Department of Health, 2012). It is important for future trials engaging NHS primary care practitioners in training and research; to consider research as part of the contractual agreements with NHS dental treatment providers with potential links to remuneration for each case recruited with data collected (Tickle *et al.,* 2011; Koch, 2013; Dahlström *et al.,* 2015).

As all dentists needed to have completed the agreed number of cases (100 per dentist per year) in order to complete the training and were remunerated to treat these patients, recruitment of patients to be treated during training was not an issue. However, ascertaining the completed logbooks from every dentist was difficult. Importance was given to the cases discussed as part of the end of year examinations and the logbooks were assessed more informally during the training. In order to collect complete data from all dentists to assess change in skills during the course, it may have been better to formally collect completed cases as represented by a completed logbook summary and accompanying radiographs on a monthly basis as part of the training requirement. This was difficult in this study, as due to the delays in gaining ethical approval; there was reliance after the event on dentists submitting the cases they completed during the early part of training. As there was little formal emphasis on this even at later stages of the training. Collecting logbook data was reliant on goodwill, even though maintenance of this data by these dentists was a stipulated component of the training initiative.

As patient recruitment post-training is dependent on dentist recruitment for this design of study, steps to empower clinicians to take ownership and engage in research include training in research principles, electronic data collection, regular practice visits and support from research project workers, help with adapting consent/data collection into daily practice and appropriate contractual agreements and remuneration for their time. Additional incentives might be research involvement within continued professional development requirements for GDC registration. The availability of research participation with appropriate remuneration is likely to be seen as a route for income generation and possibly as a practice builder (Mjör, 2007; Draper *et al*., 2009; Tickle *et al.,* 2011).

10.3.1.2 Patients

Patient recruitment post-completion of training from some dentists was high and will be linked to having a continued DES NHS contract for provision of the service. The proportion of patients recruited in comparison to the contractual agreement for the number of patients to be treated within the DES NHS contract is unknown. Retention rates were also high as shown in Table 44, with 81% of recruited patients returning OHIP-EOM questionnaires post-treatment and 42% returning questionnaires at follow-up. This was significant considering that only 8% of patients stated that they were receiving this treatment from their usual dentist (Section 7.2), meaning that the majority would have returned to their referring practitioner for definitive restoration of the tooth as well as review and maintenance because this aspect was not commissioned from the DES. The demographics of the recruited patient group is unlikely to be representative of the transient multi-ethnic population of London, as almost three quarters of patients recruited stated they were of white ethnic background and almost half stated being educated to university degree level or higher. This may be representative of the geographical area covered by the DES who recruited most patients or may be reflective of the types of patients willing to provide feedback or engage in research or would wish to retain a given tooth. In London, the reason for patients participating in clinical trials have been reported as mainly due to altruism and perceived potential self-benefit (Newington & Metcalfe, 2014; Moorcraft *et al.,* 2016), and barriers to engaging are described as logistical reasons including not enough support for those who do not speak English (Newington & Metcalfe, 2014). In this study, Language Line London was available for those who required translation. However, this is time consuming and therefore may have been a barrier for some dentists and some patients.

Loss to follow-up of patients was expected in this research, especially as long-term follow-up was involved (Farzaneh *et al.,* 2004). The response rate of patients recruited into the study was 24% at follow-up if the availability of clinical and radiographic data (logbook data) were taken into account, which as 10% lower than what was expected (section 4.15). If only the response rate of patients who completed pre-, post-, and follow-up questionnaires was considered, the response rate was 37%, which was higher than expected (Farzaneh *et al.,* 2004). This was a reasonable response rate considering that at the inception of the course, follow-up was considered the responsibility of the referring general dental practitioner and the DES was not funded for follow-up. These patients returning to their referring dentist for maintenance and follow-up may explain this, which hinders continued learning and audit of outcomes by each clinician providing root canal treatment. Commissioners remunerating this patient clinical contact at follow-up may encourage better follow-up. It is difficult to know if the low rate of follow-up is related to patient non-compliance or the commissioning arrangements. Additionally, data available at follow-up is likely to be low in a transient population such as that in London, and therefore must be compensated for during recruitment and through commissioning arrangements.

Although financial incentives could persuade certain subgroups of the population to participate in research, the impact of such on recruitment and retention is not known, as motivations for participating in research is diverse (Grady, 2005). It has been suggested that incentive payments to participants may influence their reporting or feedback and therefore could ‘diminish the integrity of the study’s findings’ (Bentley & Thacker, 2004). Payments for taking part in research may raise ethical difficulties and as such are not always encouraged where there is potential for harm, as they may be considered exploitative, however, reimbursement for time and expenses is recommended (Bentley & Thacker, 2004; Draper *et al.,* 2009). In relevance to this design of study, there is potential for harm if patients are recruited and randomised in to the group receiving root canal treatment from a clinician that has not undertaken additional training to be able to treat teeth of moderate difficulty for example. If procedural errors are performed the tooth may become unrestorable and need extraction. Reimbursement may be monitory or in the form of vouchers, however the demographic of the population attracted by each should be considered, as the impoverishment of the subject is relevant and may be a potential source of selection bias (Bentley & Thacker, 2004). Possible patient incentives for participation should be considered in future trials, such as reimbursements for time or expenses following guidance on their use (National Health Service Health Research Authority, 2014).

In accordance with the Steele Report (2009), complex treatments such as endodontics should be performed on patients with good general maintenance of their dentition, where primary disease is under control and patients demonstrate motivation to maintain their natural teeth. This ensures that resources are allocated to areas where the outcomes are likely to be good in the long term, and in the case of root filled teeth, not failing due to the development of caries or the progression of periodontal disease, both of which can be prevented on the whole with patient compliance with adequate prevention of dental disease. In the future, if the care pathway protocol being piloted (Department of Health, 2014b; NHS England, 2015a) is successful, the implication is that patients receiving this DES service are motivated to return to their dentist for review and maintenance, thereby ensuring that follow-up occurs.

10.3.2 Development of Quality Assessment Tools

The starting point of this research was the development of objective and easily usable measurement tools for capturing data in a primary care setting and ways of scoring quality. Although there is a large pool of literature in the field of endodontics, this was still challenging, as the current practices and measurement of outcome may be considered subjective and echo the subjectivity of measuring outcomes and quality in dentistry generally (Tickle & Campbell, 2013). At inception it was agreed that measurement tools developed for this study should be based on current clinical practice in order to integrate these into daily practice in any setting, and explore the reliability of these practices.

The scoring system for the treatment process was based on literature on prognostic factors for the outcome of endodontic treatment as outlined in section 4.3. Data capture instruments were developed as part of this course to facilitate good record keeping and some of the prognostic factors were published post implementation of the data capture forms (Ng *et al.* 2011a). Therefore, it was not possible to capture data such as if EDTA solution was used as a penultimate wash followed by a final rinse of sodium hypochlorite in secondary root treatment cases (Ng *et al.* 2011a). Similarly, sealing the root fillings with a 'canal orifice seal' (Ng *et al.* 2011a) was not included in the data capture forms used in this initiative. This would have been helpful in identifying the provision of a coronal seal by the DES. In view of this, future trials should capture this information as part of the routine record keeping and data collection process, preferably using an electronic system (Bourke *et al.,* 2004); these should be simple to avoid poor quality data (Department of Health, 2014b).

The numerical scoring systems for determining the complexity of cases was difficult to implement as quantifying complexity is subjective, and aspects of tooth which make treatment complicated, are not always cumulative in arriving at a higher complexity score. Previously used scoring systems have allocated numerical weights to the complexity levels, scoring 1 for low, 2 for moderate and 5 for high complexity. The sum of the scores has been used to grade complexity (American Association of Endodontists (1999), the Canadian Academy of Endodontics (1998), and the Endodontic Treatment Classification (Ree *et al.,* 2003). In 2007, the Index of Restorative Dental Treatment Need (RIOTN) developed by the Royal College of Surgeons of England (Falcon *et al.,* 2001) was evaluated as a system for grading the complexity of root canal treatment in the UK (Muthukrishnan *et al.,* 2007). The RIOTN was used to assign a complexity grade to 186 teeth (using clinical and radiographic findings) by the chief investigator, retrospectively. Sixty randomly selected cases were then reassessed, in the same way one year later, by the chief investigator, a consultant in restorative dentistry and a Vocational Trainee who had been qualified for six months. Weighted Kappa for intra-observer agreement was 0.636. Weighted Kappa for inter-observer agreement with the consultant in restorative dentistry was 0.570 and 0.223 with the Vocational Trainee. Although the system was seen to be rapid and easy to use the reproducibility was ‘moderate to poor’. A variety of reasons were highlighted including ambiguity and subjectivity (Muthurishnan *et al.,* 2007). A tooth could score low complexity in most domains and then have a high complexity score for one domain, which would result in the case being categorised as high complexity. However even with a weighted scoring system the total score could amount to moderate complexity. The total quantitative score often does not represent true complexity without a qualitative description. There was no ideal measure of complexity using numerical values alone. These scoring systems are not specific to complexities relating to the tooth only but also encompass patient factors that complicate root canal treatment (Morand, 1992; Ree *et al.,* 2003).

Although conducted on a daily basis across dental clinics in the world, scoring radiographs is neither uniform nor without error, as a plain radiograph represents a two-dimensional view of a three-dimensional object determined with the subjective element of the human factor. This study revealed the impact of training and calibration on reliability, although maintaining high levels of agreement over time required repeated training and calibration. This was further highlighted when the same examiners scored 24 endodontic training blocks for procedural errors, working length and taper. The Kappa scores for both inter- and intra-examiner reliability was significantly higher than those for scoring the same domains using radiographs. In normal clinical practice practitioners score radiographs independently and rarely verified by another. This study showed that there is valuable learning in discussion with experts to arrive at opinions about radiographic appearances, which then may feed the decision making process.

The inter-examiner reliability scores were high for tooth position and type of treatment. It was expected that tooth positioning would receive a Kappa score of 1 and the variance may be as a result of incorrect entry of data into spreadsheets. Treatment type can be deceptive as the presence of separated instruments can be difficult to determine radiographically. Endodontic re-treatment can also be subjective, as in some cases, it was not always possible to determine from a radiograph if the tooth had previously been accessed and root canal treatment attempted. Kappa scores for scoring the quality of radiographs were variable ranging from 0.2 to 0.74. Resorption, root curvature, working length and healing received the poorest Kappa scores. The improvement seen with further training was not maintained when a much larger number of radiographs were scored. This may reflect a much larger variation in quality of radiographs or difficulty maintaining concentration for lengthy periods of time. Both examiners scored the radiographs in batches of 30-40 to reduce fatigue. If in doubt, examiners were advised to present the lowest score. Although every effort was made to score the radiographs as soon as possible after training and calibration, due to logistic reasons scoring was completed 4-8 weeks after training and calibration. It was not possible to calculate the intra-examiner reliability for healing due to the small number of cases scored.

Other studies on scoring of radiographs for quality of root filling had also reported low levels of agreement (Reit & Hollender, 1983). In the current study, agreement between examiners for radiographic scoring ranged from 69.5% to 85.2%. Previously published Kappa scores for complexity of cases, scored using radiographs, have been between 0.22 – 0.57 for inter-examiner reliability and 0.64 for intra examiner reliability (Muthurishnan *et al.,* 2007). In the current study, inter-examiner reliability Kappa scores varied from 0.18 – 0.99 and intra examiner reliability Kappa scores varied from 0.22 – 1. The agreement levels were in excess of 70%. The Kappa scores for measuring healing using a radiograph was low (0.35) however the agreement level was reasonable (75%). When intra examiner reliability was measured against the final agreed score, there was some improvement in Kappa scores and agreement, which may reflect the learning that has taken place during discussions of cases to agree a final score. The subjective nature of scoring radiographs is illustrated by the learning gained during the discussions that took place during training of the examiners.

Arbitrary guidelines exist for the acceptability of Kappa scores. Some consider a good kappa score to be >0.8, substantial is considered to be 0.61-0.8 and moderate is considered to be 0.41-0.6 (Petrie & Watson, 1999), others suggest Kappa values <0 indicate no agreement, 0–0.20 indicated slight agreement, 0.21–0.40 indicated fair agreement, 0.41–0.60 indicated moderate agreement, 0.61–0.80 indicated substantial agreement, and 0.81–1 indicated almost perfect agreement (Landis & Koch, 1977). Fleiss (1981) suggested that Kappa values over 0.75 were excellent, 0.40 to 0.75 were fair to good, and below 0.40 were poor. However, Kappa scores are higher if codes have equal probability of being chosen, if the two observers distribute codes asymmetrically and as the number of codes increases. Therefore, a single kappa value cannot be regarded as universally acceptable (Bakeman 1997). It is better to base Kappa values depending on the number of codes, their probability, and observer accuracy. For example, given equiprobable codes and observers who are 85% accurate, the value of Kappa is 0.49 and 0.60, when number of codes is 2 and 3 respectively. The Kappa scores in this study are within these ranges and are acceptable for the number of codes in the scoring systems.

Although these quality assessment scales can be used in routine practice by the clinician providing the treatment, in research, in order to avoid bias, it is recommended that trained and calibrated examiners award scores for outcome in areas of high subjectivity such as plain film radiography.

10.3.3 Use of Endodontic Training Blocks

Although endodontic training blocks have been used in previous studies for training (Section 2.5.7.2), technical skills *in vitro* may be better assessed using technological advancements such as computer aided simulated training or endodontic training blocks that have the same Knoop hardness of natural teeth, mounted in phantom head units in a simulated laboratory. Computer aided technology will allow more objective measurement of outcomes, especially if the experience can be closely matched to the clinical situation. These endodontic training blocks were a training device in the course, which secondarily was used for assessing technical quality. They did lend themselves to assess changes at three distinct time points (on the first day of the course, end of Year 1 and end of Year 2). The endodontic training block prepared on the first day was a representation of the skills learned by the participants prior to the commencement of the course.

It may be argued that it is difficult to assess technical skill in endodontics using endodontic training blocks alone as they present a highly artificial situation. However, these standardised blocks are canals of a predetermined size, shape and curvature and have been used in other studies (Tharuni *et al.,* 1996; Zmener & Banegas, 1996; Coleman *et al.,* 1997; Martin *et al.,* 1997; Thompson & Dummer, 1997; Kum *et al.,* 2000; Calberson *et al.,* 2002; Yang *et al.,* 2006). In this study, endodontic training blocks were viewed without magnification by independent examiners. This may introduce a level of subjectivity, which appeared consistent between time periods for the same examiner but was variable between examiners. The intra examiner reliability Kappa scores varied between 0.78 and 1 for the various domains. The inter-examiner reliability Kappa scores varied between 0.52 and 0.83 for the various domains. The use of endodontic training blocks is useful in standardising the complexity of the teeth to be treated however is an artificial situation somewhat dissimilar to clinical treatment. An important finding was that the reliability of the scoring of these three-dimensional objects was better than scoring of radiographs. In future studies using endodontic training blocks, those with more realistic anatomy and knop hardness of 40kg/mm^2 should be used (Weine *et al.,* 1975; Khalilak *et al.,* 2008). In the longer term it may be possible to use virtual reality techniques for standardisation of training and assessment of root canal procedures (de Boer *et al.,* 2013).

10.3.4 Use of Radiographs

It has been reported that plain film radiographs are not particularly reliable for assessing the quality of root fillings (Eckerbom & Magnusson, 1997; van der Sluis *et al.,* 2005). However, this is current practice, in adherence to ESE guidelines (2006) as shown in Appendix D.

This study used a combination of digital and plain films, both converted to JPEG format for assessment. A problem unique to this study of general dental practitioners in a busy NHS dental practice was the logistical and financial difficulty in administering a standardised approach to taking radiographs. Standardisation of radiographs was difficult to implement and therefore, no attempt was made to standardise the radiographic equipment or clinicians. The course teaching involved the use of radiographic assessment using film holders as standard to reduce the risk of errors related to film positioning.

Standardised reproducible radiographs can be taken using bespoke putty matrices for positioning, employing a uniform radiographic system. The construction of custom film holders for each patient using holders modified with putty indices to reproduce angles and positions of the radiographic films to allow direct comparison of radiographs taken at each stage of treatment and review is likely to have proven very difficult in terms of compliance from the DES participants working in busy practices. There may be scope to consider the use of CBCT. The use of routine CBCT was not practical and not ethical due to the increased radiation dose to patients (Patel *et al.* 2015).

The radiographs scored in this study included plain films photographed on a fluorescent viewing box without magnification and digitised into JPEG format. The digital radiographs were exported from the various digital systems and saved in JPEG form according to opinions gathered from two independent radiologists and similar approaches have been taken in other studies (Molander *et al.,* 2007; Dahlström *et al.,* 2011; Dahlström *et al.,* 2015). As actual measurements were not made from the radiographs, little further information was to be gained from saving these files in either RAW or TIFF forms. Ideally all radiographs should be viewed on specific systems with matching software and screen/monitor, as recommended by manufacturer of the radiographic system, and saved in unchangeable form; however this was not possible in this study due to logistical reasons. There may be value in exploring the effect of using a variety of digital radiographic systems with system-specific viewing screens and software. Preferably, all plain films should be retained for this study and viewed on a fluorescent light box under magnification of 2.5 in a darkened room (Ng *et al.,* 2011a) and all digital radiographs should be saved in their raw format and viewed using a high-resolution colour cathode ray tube.

The reliability of the scoring system when used with radiographs was variable. The intra examiner reliability Kappa scores varied between 0.43 and 1 for the various domains. The inter-examiner reliability Kappa scores varied between 0.11 and 1 for the various domains. The reliability was significantly lower when comparing radiographs (2-dimensional) with endodontic training blocks (3-dimensional). Discussion and reflection of cases by two examiners collectively led to an increase in the reliability as a result of learning, as in other studies (Alanai *et al.,* 2011), although this was not maintained over long periods. This implies that the reliability of the current practices without further training after graduation may also be low (Eliyas *et al*., 2016).

Other studies have assessed the quality of root canal fillings and healing following education in the use of rotary instrumentation (Dahlström *et al.,* 2011; Dahlström *et al.,* 2015; Koch *et al.,* 2015). The reported use of treatment techniques was ascertained via questionnaire surveys (Dahlström *et al*., 2011; Koch *et al.,* 2009; Dahlström *et al.,* 2015; Koch *et al.,* 2015), whereas, in the current study, the logbook allowed recording of a variety of aspects of root canal treatment in a standardised manner, following training in record keeping. Due to logistical reasons, no attempt was made to verify data in the logbooks with the patient's clinical notes, with complete trust in the accuracy of the information provided, thus giving credit and partial ownership of data to the participant dentists. In the study by Dahlström *et al.,* (2015) the reported Kappa scoring was for the appearance of the root canal filling post operatively using a 5 point scale for length, seal and taper of root canal filling. The variability of an ideal tapered shape of a canal may assume less significance in the future with more widespread use of rotary instrumentation. It was not clear if discussion took place or if scoring was independent. The assessment was performed for each root of a tooth. The only procedural error assessed was canal transportation and this was using a dichotomous scale. Dahlström *et al.,* (2011) reported intra-examiner Kappa scores reaching 0.85 again using the same scale and it was implied that examiners assessed the quality of root fillings together to reach a consensus. These Kappa scores are not comparable with the current study due to the number of points in each scale. Koch *et al.,* (2015) also assessed the quality of root filling and healing after adoption of rotary instrumentation and single cone obturation in the Public Dental Service in Sweden, using a large sample of teeth before and after training. The inter-examiner Kappa scores for root filling quality at completion of treatment and follow-up were reported as 0.73 and 0.75 for the PAI scores (5 point scale), 0.81 and 0.84 for the density of root canal fillings (dichotomous scale) and 0.87 and 0.89 for the distance of the root canal filling from the radiographic apex (3 point scale); however it is worth noting that disagreement was present in almost half of the cases assessed and a third examiner was required to reach agreement in 72 cases (Koch *et al.,* 2015).

10.3.5 Oral Health Related Quality of Life

Since the development of the Oral Health Impact Profile (OHIP) 1994 (Slade & Spencer, 1994), various versions of the questionnaire have been used in order to understand the impact of endodontic treatment on quality of life (Dugas *et al.,* 2002; Gatten *et al.,* 2011; Hamasha & Hatiwsh, 2013) as described in Sections 2.3.4 and 2.5.5.

Oral health related quality of life does not only relate to endodontic disease but also to other oral diseases such as caries, periodontal disease, tooth loss and oro-facial pain as well as sociodemographic factors (Steele et al., 2004; Cunha-Cruz *et al.,* 2007; Lopez & Baelum *et al.,* 2007; Luo *et al.,* 2007; Brennan *et al.,* 2008). Key endodontic factors associated with oral health related quality of life, using the OHIP-14 questionnaire, have been studied recently, although the study consisted of data collection as part of one episode of endodontic treatment and not change in OHIP-14 scores following treatment (Liu *et al.,* 2014). Pre-treatment, OHIP-14 and visual analogue scores were ascertained from a convenience sample of 412 patients (in a teaching hospital, to be treated by undergraduate students), followed by clinical data relating to presence of caries, fillings, missing teeth, periodontal status and endodontic status of teeth requiring root canal treatment. Presence of a periapical radiolucency using PAI has also been assessed (Ørstavik *et al.,* 1986). More than half of the sample required root canal re-treatment. Significantly higher OHIP-14 summary scores were seen for patients who were receiving root canal re-treatment compared to those who had no experience of endodontic treatment. Key predictors of poor oral health related quality of life were patient's age, multiple teeth requiring root canal treatment and pain ratings (prior to endodontic treatment) using the visual analogue score (Liu *et al.,* 2014). The OHIP-14 questionnaire was considered sensitive to endodontic disease on quality of life impact, with higher impact when there was pain and discomfort (Liu *et al.,* 2014).

The OHIP-EOM questionnaire used in this study was developed, validated and tested in a teaching hospital setting (Rasheed, 2012). The future use of this tool could be combined with assessment of the dentition and symptom scored as described in Liu *et al.* (2014), prior to completion of the questionnaires at each time point. This would allow better recognition of specifically endodontic factors that may contribute to oral health related quality of life.

10.3.6 Quality of the Coronal Seal

Although the quality of the coronal restoration was also assessed in this feasibility study, it was likely that this service had been provided by the referring GDP (who was the same person for approximately 8% of the patients who participated in the study). It was not the responsibility of the

DES as per the commissioning arrangements in the service. This may account for the observation that a significant proportion of patients seen at the follow-up were considered to have had an 'unsatisfactory' coronal restoration on the root canal treated tooth. In future, it may be appropriate to consider the coronal restoration as an important part of the service provided by a DES in endodontics, as this is a prognostic factor for outcome of root canal treatment (Aquilino & Caplan, 2002; Farzaneh *et al*., 2004; Salehrabi *et al.,* 2004; Ng *et al.,* 2008a; Ng *et al*., 2008b; Tickle *et al*., 2008; Ng *et al.,* 2011a).

10.3.7 Collection of Data

There was reliance on the primary care practitioners to ensure data were collected in a timely manner. This was not an issue with logbook data collection as good clinical record keeping was a requirement. Difficulties were encountered when pre-, post- and follow-up questionnaires were being returned to the research team and delays in sending reminders to patients. A contributory factory was that the collection and returning of questionnaires were done in batches. Such delays were not anticipated prior to the commencement of the study. A more practical and time saving procedure would have been to have instructions for the return of the questionnaire directly to the Primary Investigator. It was estimated that gathering of data would take a minimum of 12 months following completion of training. However, an extension to the data collection period (until January 2014) was required due to the difficulties of patient recruitment and compliance by DES in forwarding the required data. The follow-up should ideally involve a clinical contact (subject to the approval of commissioners) and a patient questionnaire survey. The latter could occur whether or not the commissioners facilitate patient clinical contact however as a referral service commissioned by the NHS there is reliance on approval from commissioners. Dentists who referred the patients to the DES are not part of the study therefore if their own dentist reviewed the patients; follow-up data would not be forwarded to the researchers. If this study was to be repeated in the current environment, recruitment may not be a problem as the services may now be better established; however follow-up will need careful consideration.

Lessons learned and experience gained from this feasibility study permitted the development of a process map for data collection for future studies (Figure 29). It is imperative that electronic data collection becomes an integral part of the clinical record keeping process to facilitate continuing outcome data collection in primary care. Ideally, an independent investigator should carry out the OHIP-EOM data collection in order to reduce bias and to reduce burden on primary care practitioners to recruit and collate data.

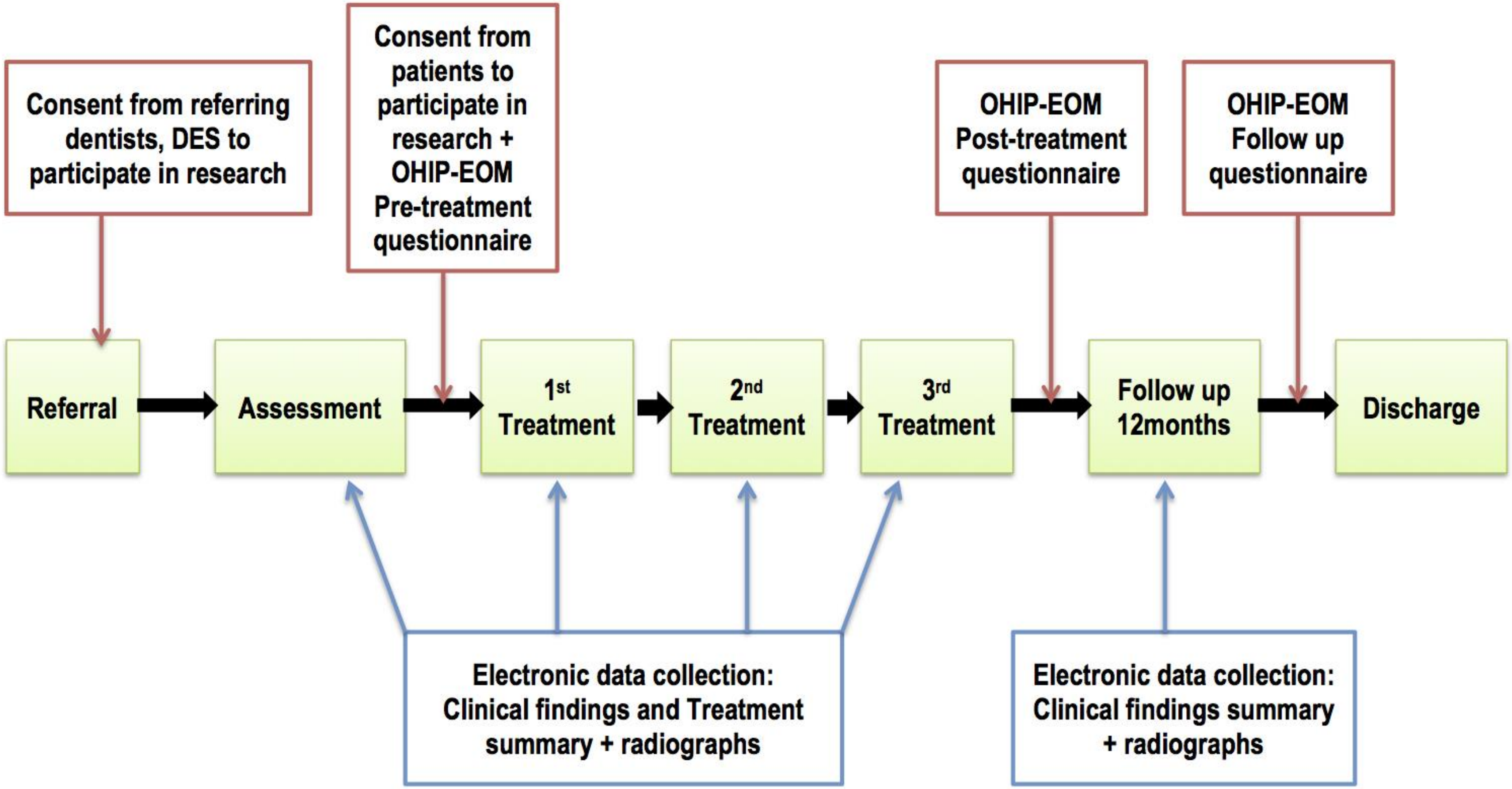

Figure 29: Ideal data collection pathway

10.3.8 Missing Data

Incomplete data except complexity level calculations were excluded in this analysis. Domains of complexity included logbook data and pre-treatment radiographs, and much of the logbook related data were missing. However, radiographic data could still be useful (as is used in current triaging systems for referrals of patients for root canal treatment). Previous audits of the cases being treated during the training course met the 'moderate difficulty' complexity guidelines (Al-Haboubi *et al.,* 2014). For the rest of data sets, it was difficult to know the impact of missing data, as complete data were only available for less than a quarter of cases. Follow-up generated the least number of complete data sets as previously discussed. As numerous domains were being recorded in this study, there was higher probability that at least one domain may be incomplete.

10.3.9 Data Analysis

In the following section, future possibilities of using types of data collected during this study, for exploring relationships between the domains of Process and Outcomes of the quality of root canal coupled with patient related outcomes is discussed. The process demonstrates the potential for data that can be gathered using data collection and measurement tools introduced in this research.

10.3.10 Exploring Relationships between Process and Outcome

Future possibilities with this type of data are the exploration of relationships between Process (the clinical process of providing treatment and the appearance of the root filling as seen radiographically), Outcomes (healing as seen radiographically and healing as seen clinically) and Patient Related Outcomes (OHIP-EOM). Assessment of raw data was necessary to show the distribution of data among the various scores for each domain being correlated. This informs the validity of the correlations observed. The correlations are strongest when closer to one, even where statistical significance is shown. Spearman's Rho was used as the correlation coefficient of choice assuming non-parametric data and as many of the variables were not interval scales. Examples of correlations and assessment of raw data can be found in Appendix Y.

10.3.11 Multivariate Analysis

Multivariate analyses of this type of data allow understanding relationships of outcome measures at tooth, patient and dentist levels. Meaningful multivariate analysis would require a number of cases where complete sets of data were available (Treatment Process, Radiographic Quality, Clinical Healing, Radiographic Healing and change in OHIP-EOM scores). In this study, of the 135 patients recruited there were 35 patients who had completed all OHIP-EOM questionnaires, and of these 16 cases with complete clinical and radiographic data (12%) at follow-up (which ranged from 10.1 – 36.4 months). Preliminary analysis revealed that a minimum of 45 cases of complete data would be required for multivariate analysis. This would require the recruitment of in excess of 375 patients to future studies to account for this level of loss to follow-up. This sample size is not dissimilar to other reported multivariate analyses (Liu *et al.,* 2014). The loss to follow-up could be reduced using the incentives discussed in section 10.3.1.

In this pilot study, limited data sets were used to test the above concept. When 16 cases with complete data were analysed, the radiographic outcome/quality score, radiographic healing score and complexity score showed statistical significance in predicting the change in OHIP-EOM scores from pre-treatment to review and therefore a change in quality of life (Table 67). Increase in complexity score by one point increased the change in OHIP-EOM score by one, increase in score for radiographic quality of root filling by one point increased the change in OHIP-EOM score by three points and increase in healing score by one point reduced the change in OHIP-EOM score by four points. R-values stated a high correlation; however these results must be treated as a demonstration of possibility and interpreted with caution, as the sample size is small.

Table 67: Predictive factors for change in OHIP-EOM scores from pre-treatment to review

Predictor for change in OHIP-EOM scores from pre-treatment to review	Effect	95% Confidence Interval for effect		P value
		Lower Bound	Upper Bound	
Treatment Process Score	-3.188	-9.115	2.740	0.186
Radiographic Outcome Score	3.131	0.091	6.170	0.046
Radiographic Healing Score	-4.632	-7.774	-1.489	0.018
Clinical Healing Score	2.940	-2.789	8.669	0.201
Complexity Score	1.014	0.014	2.014	0.048

10.3.12 Summary of Learning from this Feasibility Study

The overriding strength of the study is the fact that data collection and analysis occurred in a 'real world' setting. Measurement tools developed proved user friendly and usable in routine data collection in primary and secondary care within the NHS and for teaching and training purposes. On a wider scale, this study shows the importance of regular training and calibration for all clinicians reporting on radiographs and using radiographs for decision-making. These mainly dichotomised scores for quality of endodontic care allow for routine recording of prognostic factors for good endodontic outcomes (Ng *et al.,* 2011a) on a larger scale, which in turn may facilitate reporting of endodontic outcomes in NHS dentistry and possibly enable multilevel modelling in future research.

10.4 Pilot Study Findings

In medicine, general medical practitioners (GPwSIs), nurses, allied health professionals, pharmacists and practice managers with special interests have been described (Pawson *et al.,* 2016). Outcome data, usually in terms of service evaluations, for GPwSIs have shown that in some disciplines of medicine patients that would be referred to secondary care could be reduced by the use of GPwSIs (Gilbert *et al*., 2005). However, studies assessing actual figures show that the effect of the introduction of GPwSIs on referral rates to hospitals is variable and unpredictable (Rosen *et al.,* 2006) and can lengthen the pathway for patients (Rogers *et al.,* 2008). Where patient related outcomes were assessed for dermatology patients seen either by GPwSIs or a hospital outpatient department, there were no significant differences in the patient perceptions or acceptability of the service and patients preferred to be seen in the community; however clinical parameters were not measured (Salisbury *et al.,* 2005). The costs of seeing a GPwSI, has been suggested as 75% higher than being seen in a hospital outpatient department where a junior member of the team may see the patient rather than a consultant, therefore be less costly (Coast *et al.,* 2005). Others have intimated that costs could be lower for patients seen by GPwSI compared to secondary care (Ridsdale *et al*., 2008). The difficulties of assessing the outcome of GPwSIs using randomised controlled trials and comparing 'like with like' have been asserted (Pawson *et al.,* 2016). Few similar studies exist for dentists with a special interest or enhanced skills.

Unlike medicine, DES were not developed to reduce the workload of secondary care but to allow better access to care for those not receiving it with their primary care practitioner and also not fulfilling the guidelines to be treated in secondary care. In oral surgery, access, cost of service, patient and referring dentists' views have been reported (Pau *et al.,* 2010). The service was found to be cost effective and viewed positively by both patients and dentists using the service (Pau *et al.,* 2010). In endodontics, it has been shown that referral via consultant triaging gives a more efficient patient pathway compared to other models of triaging (Al-Haboubi *et al.,* 2014). In Periodontics, a lecture series and calibration exercise was used to train DES and patient, referring dentists and DES perspectives of the service were positive with favourable clinical outcomes reported (Cheshire *et al*., 2011). The outcome of clinical parameters of periodontal disease differs that of root canal treatment, as there is paramount importance of patient motivation on the stabilisation of periodontal disease. This study is the first to longitudinally measure outcomes at all levels of training and treatment involving DES.

Quality assessment tools developed for determining the impact of postgraduate training programmes for GDPs in the provision of root canal treatments were shown to be useful and allowed quantitative assessment of the change in skill of treatment providers, before and after training. It was possible to engage GDPs in research within primary care and incentives for engaging practitioners (namely structure and remuneration) were identified.

10.4.1 Change in Skills with Training and Experience (Part 1, Objective 1)

This study demonstrated that it is possible to assess change in skills within the sub-discipline of root canal treatment in dentistry. Preliminary data showed that improvement in skills can be attained with a combination of lectures, seminars, and hands-on practical teaching within a simulated environment intermingled with real life experience within a general dental practice, where reflective practice was heavily encouraged. A large number of cases were treated in primary care with ample opportunity between training days to practise what has been taught.

This was a sample where a select group of dental practitioners (determined by the recruitment process) with an interest in endodontics and desire to develop their skills recruited and supplied the cases assessed within the study. These dentists were not compared to another control group, but longitudinally assessed at different time points in their training. It would have been ideal to have cases treated by the participating dentists prior to course, however retrospective ethical approval and consent would be required. It would have also been desirable to have a CbD at the beginning of the course to ascertain baseline academic understanding of the subject for comparison, much like the endodontic training block completed on the first day of the course. There was potential for clustering of data, as there was variation in the number of cases supplied by each clinician. Some of the clinicians did not engage in the process of recruiting patients although these clinicians had originally stated their interest in taking part in the study.

Two independent examiners, who were not required to agree a common score, scored final examinations for the recruited dentists. This could have affected the analysis of the change in score, but probably in a less uniform way. It was noted that the change in score from Year 1 examination to Year 2 examination was consistently higher for the internal examiner than for the external examiner. This may reflect a degree of bias. The CbD marking sheets and descriptors should have been standardised for the first and second year assessments, but as these were being developed during the course, there was evolution of both as the course progressed. Validated forms were unavailable for this particular course and therefore it was necessary to develop these as part of the course. The marking scheme used broad descriptors as well as reference to the criteria of moderate difficulty. Additionally work based assessments could form part of the assessment of competence (Mattheos *et al.,* 2009).

Our findings represent current clinical practice and represent data for a varied group of general dental practitioners. Other evidence is not available to assess training techniques and identify changes in skills in general dental practice in the UK. National implementation of complexity levels and care pathways mean that a large proportion of patients will need to be seen in primary care for treatment of moderate complexity (Department of Health/FGDPUK, 2004; Department of Health/FGDPUK, 2006a; Department of Health/FGDPUK, 2006; NHS England, 2015a; NHS England, 2015b; NHS England, 2015c; NHS England, 2015d). Our findings indicate positive changes following training methods used in this study and therefore, further investment and study in this design of training are recommended.

10.4.2 Maintenance of Skills Post-training (Part 2, Objective 1)

This study suggests that high standards of endodontic treatment are possible by enhanced practitioners practicing in primary care within the NHS. There were limitations on the number of patients treated by each DES and this was determined by that commissioned by the NHS. The quality of treatment provided towards the end of the training course was maintained after completion of the course in those that participated in the post-training research. It was possible to collect OHIP-EOM data in primary care, and the results suggest improvements in oral health over time. It has been recommended that routine data collection be embedded into practice to facilitate research in some disciplines of dentistry and should be part of all dental care (Sandy *et al.,* 2012).

In terms of the quality of treatment provided, this study demonstrated the possibility of collecting data from practitioners willing to engage in research. It was interesting to see the adoption of some techniques such as the use of an apex locator and yet not other techniques such as the use both sodium hypochlorite and EDTA as irrigants. There may be a variety of reasons for this, including availability and the cost of materials as well as perceived importance of the task. For example, the use of EDTA as a penultimate wash in re-treatment cases has been supported by the literature (Ng *et al.,* 2011a), however was only used in 31 (40%) of the 77 re-treatment cases. There may be an issue of reporting bias in the use of rubber dam, as the use of rubber dam is considered mandatory for root canal treatment. Other reports of adoption of techniques in root canal treatment show low levels of adherence to guidelines and recommendations, which is not echoed in this study. As shown in Section 2.5.4, in different countries, variable use of rubber dam (0.9% - 47%), electronic apex locators (2.7% - 70%) and Sodium hypochlorite (19% - 95%) have been reported. In the UK, it has been reported that about 39% to 60% of dentists reported that they never used rubber dam for root canal treatment (Whitworth *et al.,* 2000; Lynch & McConnell, 2007). In Wales 45% reported never using rubber dam, 89% of respondents stated that working length was established using radiographs and 19% used Sodium Hypochlorite as an irrigant

(Jenkins *et al.,* 2001). More recent surveys show improvements, with 30% using rubber dam, 35% using electronic apex locators and 75% using sodium hypochlorite for root canal treatment (Palmer *et al.,* 2009). In our feasibility study, very significant improvements were seen in all areas of root canal treatment, with excess of 80% using rubber dam and an electronic apex locator, and all reporting the use of Sodium Hypochlorite as an irrigant.

The mean score for complexity was 'moderate' as expected, therefore supporting the robustness of the triaging process after training. Some patients were noted to have unsatisfactory coronal restorations at the follow-up. The DES did not place these restorations, as their patients were referred and returned to the referring practitioner for the definitive coronal restoration. In view of the available literature pertaining to the influence of a satisfactory coronal restoration on the outcome of endodontics, it may be prudent for the practitioner providing endodontics to provide the coronal seal, as previously discussed.

Oral health related quality of life (OHIP-EOM) scores improved from pre-treatment to post treatment, although not as statistically significant levels, until follow-up. The difference from pre-treatment to post treatment may not have been statistically significant because of the time required for the natural process of healing to occur after root canal treatment (Huumonen & Ørstavik, 2013; Azim *et al.,* 2016). Also, post-operative pain and 'flare up' after placement of the root canal filling is possible (Glennon *et al.,* 2004; Ng *et al.,* 2004; Sathorn *et al.,* 2008; Alves, 2010; Ng *et al.,* 2011a Wong *et al.,* 2015). Persistent post-operative pain even with 'successful' root canal treatments has also been reported (Polycarpou *et al.,* 2004). In some patients, symptoms could have improved soon after treatment and remained stable at follow-up. Therefore it is more appropriate to only use pre-treatment and follow-up OHIP-EOM questionnaires to ascertain improvement in quality of life after root canal treatment.

10.4.3 Participant (Patients) Views of the Service (Part 3, Objective 2)

Results of this feasibility study suggest that patients are willing to support service evaluations and were happy with new innovations that helped save teeth within the NHS. It was possible to collate information about patients' beliefs of their general and oral health as part of collecting service evaluation data. Positive feedback received should encourage similar services in the future.

10.4.4 Participant (Dentists) Views of the Course (Part 4, Objective 2)

This study provided an insight into the experiences and views of dentists who undertook a training course to enhance their skills in endodontics in order to be able to provide a higher quality endodontic treatment within their NHS practice. There is limited literature in this area within the NHS in England as many of the surveys have been around new graduates and their experience of undergraduate training or vocational training (Murray *et al.,* 1999; Bartlett *et al.,* 2001; Patel *et al.,* 2006).

Options available to gather information on the opinions of participating dentists on the training programme were written questionnaires, interviews, and focus groups. The advantage of using open questions is that the responding individual has time to reflect on the answers, and has the freedom to express opinions without being influenced by the investigators who were also in the teaching faculty. This freedom of expression was further enhanced by permitting type written answers and providing investigator self-addressed envelopes. In addition, the questionnaires were sent to the DES participants after their final examination and before they received their examination results and before the final feedback session of the training programme. The expectation was the collection of information in an unbiased and a practical manner. All questionnaires were returned in the provided envelope on the final feedback session.

Alternative methods of continuing education on professional practice and health care outcomes was discussed in section 2.5.2, where it was shown that printed educational materials, didactic teaching without interactive workshops, audit and feedback are unlikely to change professional practice significantly (Freemantle *et al.,* 2005; O'Brien *et al.,* 2007; Jamtvedt *et al.,* 2006; Ivers *et al.,* 2012; Ivers *et al.,* 2014). Simulated and virtual reality learning of technical skills has been shown to be as effective in dentistry as bench top learning (Clancy, 2002; Jasinevicius *et al.,* 2004; LeBlanc *et al.,* 2004) and such technology is now available for training in the provision of root canal treatment (de Boer *et al*., 2013). This with reflective learning and portfolios is ideal (Boyd & Fales, 1983; Buckley *et al.,* 2009; Dannefer & Henson, 2007). These techniques of teaching were embedded within the course and the perceived outcome is that knowledge, understanding, and technical skill improved for the participants within this course. The participants stated that wider change in practice occurred as a result benefiting the participants and their patients.

There were limitations in the analysis of written responses and therefore the inferences drawn are not extensive. In order to allow greater exploration, structured interviews are better, with opportunity to gain depth within the answers. As a result, inferences and theory from small, written datasets should be interpreted with caution. Ideally these open ended questions should be developed using an expert panel in conjunction with focus groups or interviews to better understand the participants understanding of the questions, their intent and appropriateness of the response format, followed by revision and piloting of the instrument (Mullens & Kasprzyk, 1996). Log diaries kept throughout the course may have been a suitable method of validation of the questionnaire and these would be better than a onetime questionnaire which is reliant on long term memory and summative ability of the participant. The validity of the questionnaires can be assessed using the participant views that were gathered as part of a larger service evaluation of the course.

Motivations for deep and surface learning have been described in Section 2.5.1. Strategic learners (Entwistle & Ramsden, 1983) who identify what they need to learn before beginning may to some extent reflect this group of dentists in their approach to this course. It is difficult to know if the organisational components of the course highlighted as needing improvement would have been recognised without hindsight. There is likely to be an impact of the PCT paying all fees for the course on the participants, on their views of the value of the course. From the current analysis it is not possible to know how different the views would have been if the course were self-funded.

Intentions to change practice may be inherent in those with a personality always seeking to improve. In the case of the participants of this course, they were put forward for further training by their PCT as they provide sufficient endodontic services for the PCT already. Therefore, there was an element of recommendation involved. Participants were chosen through a competitive interview process; therefore inherent desire to improve may have been a factor. From the transcripts, participants spoke of actively seeking post-graduate training in endodontics prior to embarking on this course. Previous interest in endodontics and a desire towards providing endodontic services in general practice was stated. Almost all participants cited changes in practice following the course. This may be a result of the training closely mirroring principles of adult learning theory, thereby these internally motivated learners were allowed self-directed learning with opportunity to bring their life experiences and prior knowledge to their learning experiences, with a goal in mind and didactic teaching kept relevant to practise and with a large practical component and learners feeling respected (Brookfield, 1986). This was achieved by providing prior reading and questions to think about, discussions in seminar format with everyone sitting in a circle, and asking for their thoughts and experiences relating to the topic/questions with opportunity for everyone to voice their view. Recommended small group teaching/learning with a mixture of didactic and interaction with an opinion leader was also implemented (Forsetlund *et al.,* 2009; Flodgren *et al.,* 2011). It was noted respondents stated when they felt they were not being respected for example '*… module presented in a rather top-down manner…*' (**P4, Q4**).

In order to achieve change in behaviour, Grol & Wensing (2004) recommended five steps: create a proposal for the desired change, analysis of current practice as well as barriers and incentives for change, developing and choosing ways to change practice, testing of the implementation plan, and undertaking the implementation plan with continued evolution and adaptation as required (Grol & Wensing, 2004). These steps have been implemented in training other healthcare practitioners such as general medical practitioners (Porcheret *et al.,* 2014). The first three steps of this approach to behaviour change have been addressed within this feasibility study as shown in Figure 30.

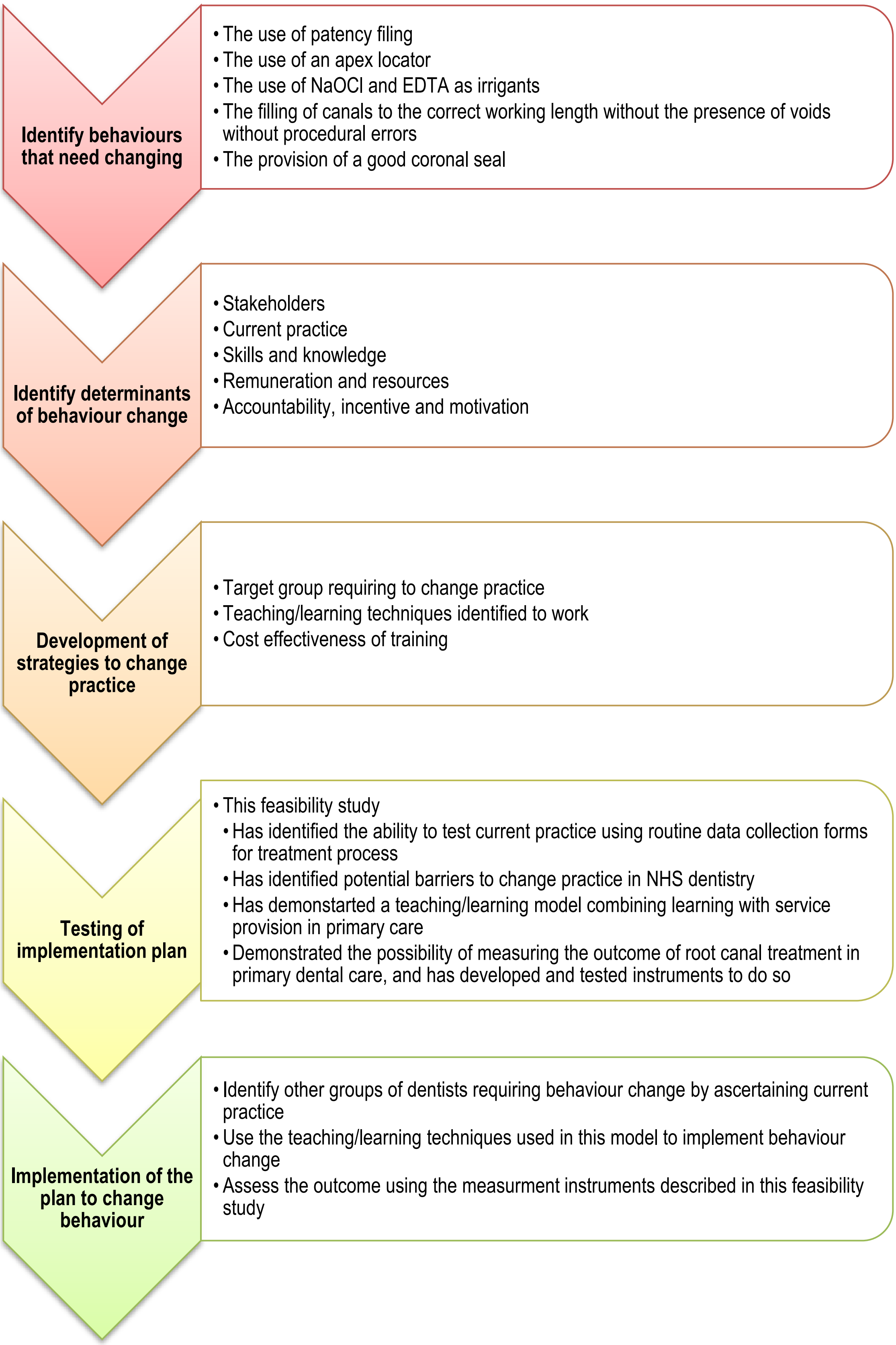

Figure 30: The implementation of changing behaviour in the provision of root canal treatment in primary dental care

Grol & Wensing, 2004; Porcheret *et al.*, 2014

Factors impeding behaviour change identified by the respondents of this course were not dissimilar to the Theoretical Domains Framework developed by Michie et al. (2005) described in section 2.5.4, such as the lack of knowledge and skills (training), beliefs about capabilities and consequences (motivation and incentives) and resources as described in section 5.5.4. The next step would be to test the implementation plan against a control group, and where necessary adapt the implementation plan (Grol & Wensing, 2004; Porcheret *et al.,* 2014; Baker *at al.,* 2015).

That remuneration is a strong impacting factor on behaviour change has been demonstrated elsewhere (Chaix-Couturier *et al.,* 2000; Tickle *et al.,* 2011). Fee payments should be strongly based on an understanding of actual costs of providing treatment. Towards the end of the course in March 2011, the commissioning environment was in flux due to White Paper presented by Andrew Lansley in July 2010, which became the Heath and Social Care Act (2012). Among the changes suggested was the abolishing of the PCTs, in favour of National Commissioning boards and Clinical Commissioning Groups (Health and Social Care Act, 2012). There were significant changes to the personnel involved in commissioning services with the loss of PCTs and the emergence of NHS England’s central commissioning body for dental care. The imminent changes anticipated with the publishing of the Health and Social Care Act 2012 led to much angst and uncertainty regarding the future commissioning of dental services. This uncertainty is highlighted in the views of the participants of this course and brings to attention the importance of stability within the NHS.

Factors that affect the learner’s experiences of learning and training should be considered in the design of future training programmes. The nature of training to be provided, available infrastructure and possible remuneration are essential components to be considered. Factors identified in this study are in agreement with other published criteria (Dolmans *et al.,* 2008; Lord *et al.,* 2012; Bos *et al.* 2015). Further research using semi-structured interviews of the stakeholders involved in this novel pilot training programme would allow a better understanding of the deeper motivations and benefits of such training in changing skills of general dental practitioners.

10.4.5 Financial Cost of the Course (Part 5, Objective 3)

Accurate estimation of the actual cost incurred in training this cohort of DES was difficult due to significant organisational changes that occurred within the NHS. Therefore the cost included in this study is estimated. In term of developing expertise, the number of hours spent practicing a craft is important (Ericsson *et al.,* 1993, Hambrick *et al.,* 2014). In this course it is estimated that delegates spent between 18,072 and 58,096 hours during the training course. Considering the cost of training specialists and providing this treatment within secondary care, the cost is likely to be significantly lower to train and provide endodontics of moderate complexity within primary care.

10.5 Implication for the Future

This training initiative was developed by the London Deanery before the establishment of HEE and the new policy and framework for educating the workforce (Health Education England, 2014/15; Health Education England Framework 15). Yet, it is central, not only to the key themes outlined by HEE, but also those by NHS England, PHE and is essential for the future plans for NHS dentistry in the UK (Department of Health, 2015/16; Department of Health, 2014a; Department of Health, 2013a). This includes improving outcomes across healthcare and the population with inclusion of research, as the NHS constitution states that all patients should be offered the opportunity to take part in research (Department of Health, 2013b). Quality based primary care research in other dental specialities is already taking place (Heasman *et al.,* 2015);

therefore the measurement tools developed in this study can be used for similar purposes in endodontics.

NHS is planning a categorisation of dental treatment into levels of complexity (NHS England, 2015a), with routine care (Level 1) being provided by general dental practitioners and the most complex care being provided in hospitals (Level 3b). Intermediate levels of complexity are to be provided in primary care whether by those with additional training or experience (preferably Level 2) or by Specialists (preferably Level 3a). The commissioning guide for restorative dentistry (encompassing endodontics) is yet to be released, potentially due to the lack of funding to employ Specialists for all intermediary levels or due to the lack of manpower with additional skills/training.

This proposed manner of training combining primary care service provision as part of the training model will be beneficial in extending skills whilst not hindering access to care during training. This feasibility study indicates that this model of training can work and be amalgamated with research in primary care where the outcomes of treatment and by proxy, training can be measured. Even after the substantial changes to the NHS structure in recent times, although some of the DES from this initiative have struggled to secure reasonable contracts with commissioners to provide the service, many have maintained contracts to provide endodontic care. For example, two DES in South West London and one DES in South East London are part of managed clinical networks (MCNs) for endodontics. In North London one DES has not only secured a NHS contract for this service but has also employed others to provide a similar service. Other parts of the country are looking to use this model of training to enhance skills in primary care, such as in rural parts of Aberdeen, in order to improve patient access to local services rather than travel to dental hospitals for treatment.

It appears possible to integrate service provision and training as part of existing networks or new MCNs for the improvement of skills in primary care (Skipper 2010, Guthrie *et al*. 2010, NHS England Introductory Guide for Commissioning Dental Specialties 2015). Acceptance for treatment within the MCN will depend on the complexity of the case, the strategic importance of the tooth and the priority level of the patient (for example those that have undergone radiotherapy to the jaws, have taken bisphosphonates or have bleeding disorders that require prophylactic cover). There is opportunity to accept a case mix of lower complexity depending on the training needs of the different levels of staff within the MCN. Consultant triaging was seen to be the most efficient pathway (Al-Haboubi *et al.,* 2014) and this could be used again. The DES or trainee DES becomes part of the network, able to dip into training on a regular basis as part of a structured course. This does not need to be a bespoke training arrangement such as that assessed in this study, but could include state or self-funded training programmes such as Diplomas and Master of Science degrees, but should also include the volume of cases treated in general practice as in this training initiative.

Training for DES within MCNs can be aligned with training provided for other post-graduate students and specialty trainees to facilitate efficient use of resources. Similar schemes involving primary and secondary care have been suggested for oral surgery (Renton & Balmer, 2013; Renton, 2013a; Renton, 2013b). The training potential of MCNs has been recognised (Guthrie *et al.,* 2010). The advantage of incorporating research into this model is that research carried out in universities and hospitals do not need to be extrapolated to different settings as the data can be collected for the different settings in the same way and compared (Heasman *et al.,* 2015). The quality assessment tools from this study could be used to assess the outcome of training. It is not clear if the numbers of cases treated by each dentists as part of the training initiative involved in this study or the method of course delivery and assessment played a part in the outcome, which may be different for other training programmes. The potential for assessing this is discussed later in Section 10.6.

A series of three recent articles concentrated on the measurement of quality within primary care dentistry in the UK (Campbell & Tickle, 2013a; Tickle & Campbell, 2013; Campbell & Tickle, 2013b). The current study addressed issues of measuring quality of dentistry within primary care and relates to the provision of root canal treatment. As suggested by Campbell & Tickle (2013a), this study developed a multifaceted approach to measuring quality of root canal treatment from patient, clinician and commissioner points of view. As recommended by Tickle and Campbell (2013), the quality assessment tools developed are conceptually accepted in published literature; the validity and reliability of which has been tested. Moreover, the use of these quality assessment tools as a routine part of dental treatment within primary care has been demonstrated. The overall project took into account Structure (training, equipment, remuneration), Process (the provision of high quality root canal treatment) and Outcome (healing and patient centred outcomes) as described by Donabedian, (1966; 1980; 1988,). Ability to improve and maintain skills of general dental practitioners using educational incentives that improve access to care was demonstrated, with insight into impact of additional training on individual clinicians, their organisation and the wider NHS (Campbell & Tickle, 2013b).

10.6 Future Studies

The intended objective of research trials to evaluate the outcome of training is to understand if the training is beneficial. An ideal trial assessing the impact of training in endodontics on the skills and outcome of treatment should ask the questions outlined in Table 68 with appropriate null hypotheses. If the course participants were to improve their skills, achieve a high level of clinical, radiographic and patient related outcomes as a result of having completed this course, this course can be considered as worthwhile. Additionally, if the course participants felt they gained more than technical abilities alone during this course and the course was found to be of reasonable cost, there would be good evidence for stakeholders to invest in this design of additional training for general dentists especially with regard to the number of cases treated for practical experience, thereby improving the quality of dental care.

Table 68: Research questions and null hypotheses for assessing impact of training in root canal treatment on skills and outcomes of treatment

Research Questions	Null Hypotheses
1. In GDPs, does additional training/experience in endodontic techniques improve their performance *in vitro* (endodontic training blocks) and *in vivo* (clinical cases using data from logbook and radiographs) compared to their performance before training/experience?	1. Additional training/experience in endodontics improves the performance *in vitro* (endodontic training blocks) and *in vivo* (Clinical cases) compared to their performance before training/experience
2. What is the quality of root canal treatments provided by this cohort of GDPs with Enhanced Skills in endodontics (post completion of training)? a) Is there a relationship between the process of carrying out root canal treatment and clinical and radiographic outcome? b) Is there a relationship between the process of carrying out root canal treatment and patient related outcomes? c) Is there a relationship between the clinical and radiographic outcome and patient related outcomes? d) Is there a relationship between the process of carrying out root canal treatment, the clinical and radiographic outcomes and patient related outcomes?	2. The quality of root canal treatment provided is good and is maintained post-training. a) There is a positive correlation between adherence to quality standards of the process of root canal treatment, and the quality of clinical and radiographic outcomes b) There is a positive correlation between adherence to quality standards of the process of carrying out root canal treatment and patient related outcomes c) There is a positive correlation between clinical and radiographic outcomes of root canal treatment, and patient related outcomes d) There is a positive correlation between adherence to quality standards of the process of root canal treatment, the quality of clinical and radiographic outcomes and patient related outcomes

As per the Medical Research Council (MRC) guidelines on Developing and Evaluating complex interventions (Medical Research Council, 2015), in order to assess the treatment outcome of postgraduate training in a branch of dentistry such as root canal treatment, the ideal study design should assess the outcome in randomised groups of dentists with and without additional training provided towards this goal. These data should be compared to a matched group of dentists who have undertaken the gold standard of training (monospecialty training enabling access to the General Dental Council Specialist List) and a randomised, matched groups of dentists who have undertaken alternative methods of training. Further, minimal statistical requirements should also be met with regard to both dentist and patient numbers for meaningful and reproducible data collection. A randomised selection of matched patients with the same position of tooth, of the same treatment complexity requiring the same treatment would need to be randomly allocated to be treated by one of each group of dentists. A design where the intervention was delivered to the control group on completion of the study would overcome ethical concerns about non-intervention with the control participants. Ethical concerns exist for the patients treated by dentists without additional training. Data relating to the process by which the treatment was carried out, healing outcome of treatment and patient related outcomes would need to be collected and analysed. Based on CONSORT guidelines (Moher *et al.,* 2010), Figure 31 is a flow diagram of the ideal study design to assess a complex intervention, such as the outcome of postgraduate skills enhancement in endodontics.

Identification of research question

- Is it an important area to research and relevant to practice?

Systematic review of the current literature

- Inclusion and exclusion criteria for studies
- Search MESH terms and search engines
- Assessment of the literature
- Has the research question already been answered?

Aim and Null Hypothesis

- Unit of analysis for each null hypothesis
- Sample size calculation for each null hypothesis
- Ethical approval
- Informed Consent for all participants
- Conflicts of interest and funding

Trial Design (Randomised Cotnrolled Trial)

- Control (dentists without further training in endodontics)
- Intervention (dentists who have undertaken gold standard training and dentists who have undetaken alternative training)

Participants

- Inclusion and exclusion criteria for dentists within the trial
- Stratified and randomised selection of matched dentists for each group
- Inclusion and exclusion criteria for patients within the trial
- Stratified and randomised selection of matched patients
- Standardised setting and location for providing treatment and collection of data
- Same tooth position and complexity

Intervention

- Training for two groups (matched group of dentists randomly allocated to one of the tree groups)
- Blinding and randomisation of dentist, patient, assessors of outcome and statistician

Outcomes

- Provision of root canal treatment to a random sample of patients
- Treatment not to be standardised as the three diffierent groups will have different training
- Blinding and allocation concealment (dentist unaware that patient is in a trial)
- Standardised data collection for all groups (treatment process)
- Blinding (dentists and patients unaware of what parts of treatment are being assessed)
- Standardised radiographs taken in custom positioning devices using the same radiographic equipment and saved unaltered in a standardised form
- Contemporaneous data collection (electronic)
- Measurement of outcomes - Validity and reliability of scoring methods (training, calibration, inter and intra examiner reliability)

Statistical analysis

- For data with a null hypothesis
- Testing for normality
- Use of appropriate statistical test for each null hypothesis

Results

- Flow diagram and losses to follow up
- Baseline demographic data
- Numbers analysed for each null hypothesis
- Harms and unintended effects in each group

Discussion

- Limitations of study
- Interpretation and generalisability of study
- Further research

Figure 31: Flow diagram of the ideal randomised controlled trial to assess the outcome of postgraduate training of dentists

As outlined in section 2.7, it is important that prior to embarking on a potentially resource heavy randomised controlled trial, a feasibility or pilot analysis is carried out in order to identify potential effect sizes, components of the intervention and data collection that may require trial and development, development of outcome measures, potential costs of the intervention, and assessment of the intervention (Medical Research Council, 2015). The London training and service pilot provided an ideal opportunity to explore the various elements of a potential trial and tested scoring methods to assess the change in skills of dentists undertaking postgraduate training in terms of the outcome of treatment provided after such training. This study therefore informs the future trials in this area of research (Figure 32).

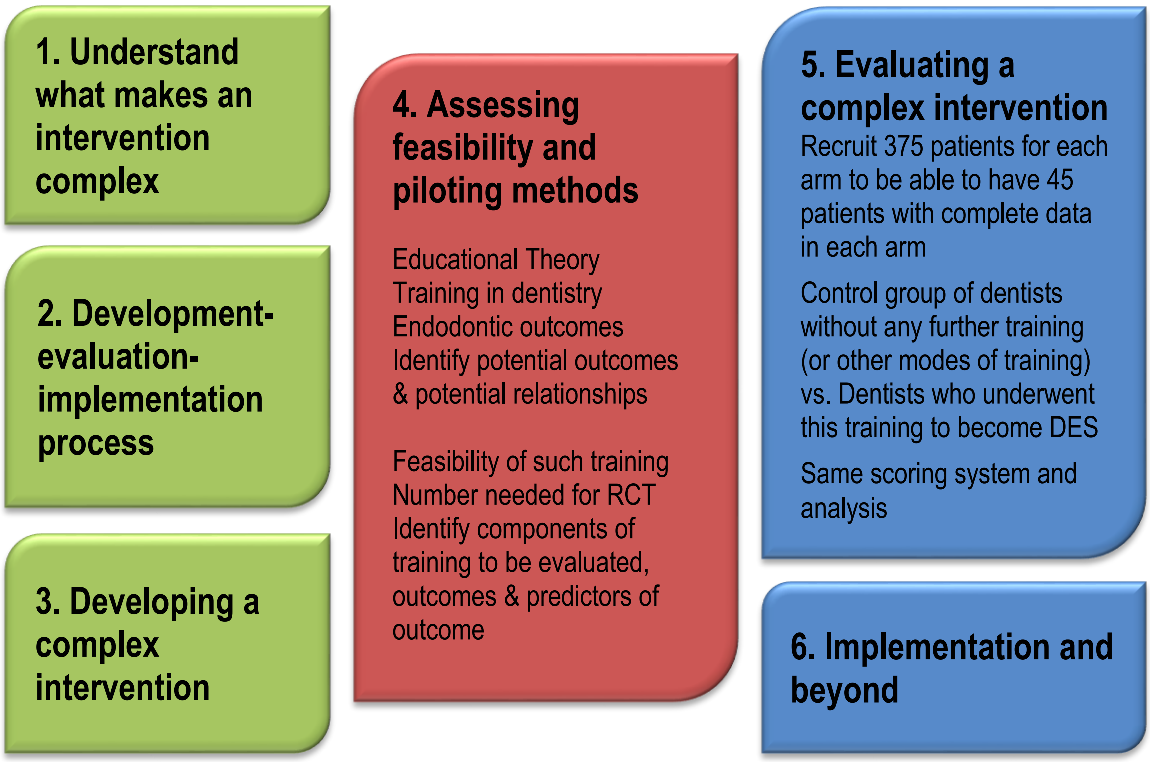

Figure 32: Summary of the current exploratory study informing next part of study

It is essential that a power calculation be performed for each aim (and therefore null hypothesis) of the study. The statistical analysis is then valid and reliable for each aim, and informs if the null hypothesis is to be accepted or rejected. The power calculation should be used to assess the correct unit of analysis and the study should state if the effect size is informing superiority, equivalence or inferiority. The power calculation should also take into account the expected rate of loss to follow-up and compensate for this (Whitley & Ball 2002). A good quality study ideally calls for a power calculation based on being able to predict the quality of a root filling as defined by a combination of treatment process, clinical and radiographic healing/non-healing, and improvement in oral health.

The most appropriate analytical strategy would be a regression analysis predicting quality of root filling with predictor variables of operator, stage of training, score for the clinical treatment process of providing root canal treatment, score for the appearance of the root filling as seen radiographically, score for healing as seen radiographically and score for healing as seen clinically as well as patient related outcome scores.

The sample size of dentists participating in this course was limited to 8 (and cannot be changed according to a power calculation), due to the course arrangements, which are beyond the scope of this study. The number of cases treated by each dentist is limited by the referral pattern to each area although the PCT and Training Course recommend that each trainee DES treat a minimum of 100 cases per year.

In line with the data derived from this feasibility study, we would expect a medium effect size and therefore would aim to recruit approximately 64 dentists per group (Norman *et al.,* 2012). Analysis of the patient based data in a future trial should be analysed using multi-level modelling to account for clustering within the data (Masood *et al.,* 2015). In order to recruit 375 patents to each arm for multilevel modelling (Figure 32), it is likely that 2-3 years of recruitment and 4-6 years of data collection will be required, however, this would depend on the commissioning arrangements and number of cases commissioned from each of the dentists.

Chapter 11: Conclusion

It is possible to engage general dental practitioners in primary care research. Outcome measures for a definitive trial have been defined and the sample size required for a definitive trial would be 64 dentists and 375 patients in each arm.

The data capture tools developed for the course was appropriate to collect treatment process data. The quality assessment instruments developed and tested in this study allowed the measurement and exploration change in skills following additional training, adoption of treatment process predictors of outcome assessed at the level of the clinician, and healing outcomes of treatment and patient experience assessed at the level of the patient.

The pilot data ascertained indicated that for General Dental Practitioners, the provision of additional skills training and experience in endodontic techniques does improve their performance *in vitro* (endodontic training blocks) in all domains measured when compared to their performance before training/experience. In these dentists with enhanced skills, the quality of endodontic treatment provided was maintained after completion of training. Favourable outcomes of healing were seen. There was a significant improvement in the quality of life scores for patients treated from pre-treatment to follow-up.

Patients viewed the care they received from dentists with extended skills positively. Participants perceived combining general practice experience with didactic teaching as beneficial for change in practice, as well as patient access and outcome. The training was estimated at a total cost of £83,050 per dentist for both years, including the cost for commissioners for the cases treated during the course. The number of teeth treated, as part of this training and after training was approximately 1600 teeth, at a total cost of £415.25 per tooth.

This pilot and feasibility study provides robust measurement tools and methodology to measure the quality of root canal treatment provided in primary care. This preliminary data suggests that a training programme combining didactic teaching with general practice experience is a feasible option for improving skills in primary care and informs future planning of training linked to service provision in primary care. It highlighted issues however, with practitioner and patient involvement, which need to be addressed in the future. The costs of such initiatives should be collected as they occur including recruitment, equipment, material and teaching costs. Patient follow-up should be encouraged in line with published guidance, with appropriate remuneration for assessing outcome and follow-up. Further research informed by the learning from this study is recommended to confirm the findings of this pilot study

Chapter 12: Recommendations

12.1 Training in Primary Care

This study has illustrated the potential for extended skills development during training within primary care settings to be used as part of the process. Regular hands-on training supported by seminars on a monthly basis in the provision of root canal treatment; while service delivery is maintained (and supported by NHS contracts) in primary care is sufficient to show improvement in adoption of techniques to improve care. It is recommended that this model of training be utilised to enhance skills of existing primary care practitioners to meet the needs of the population with some modifications including greater levels of student-teacher contact early on in training, with prominence given to gaining practical skills, short and targeted seminars, and greater discussion of cases. Individualised feedback especially with more clinical sessions in practice under supervision is recommended.

12.2 Research in Primary Care

This study has demonstrated the ability to carry out research within primary care. In order to ensure study designs meet the required recruitment targets the following should be considered:

- Inclusion of patients under 16 years old with appropriate consent procedures
- Clearly outlined commissioning arrangements which facilitate follow-up data collection
- Dedicated research staff to expedite timely collection of data
- Integration of research and adequate resources to support primary care research

12.3 Implications for Practice

This study provides measurement instruments to enable routine collection of outcome data for the process of providing root canal treatment and for healing. These should be integrated into practice in all settings (primary and secondary care), preferable as part of electronic record keeping to facilitate easy collection and analysis of data. Collection of outcome data should be continuous with appropriate follow-up to understand disease and healing processes better. Integration of the system across and within primary and secondary care will allow follow-up data to be collected in any setting by any dentist, reducing loss to follow-up.

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Appendices

Appendix A: Dental Practice Board Dental Review of the General and Personal Dental Services of the NHS 2002/3, 2003/4 and Health and Social Care Information Centre NHS Dental Statistics data for the numbers of endodontic treatments and dental extractions in adults, claimed for within the NHS from 2002/3 to 2014/15 (Data for Figure 3)

Year	Claims with endodontics	Clinical Treatment items with endodontics	Claims with Extractions	Clinical Treatment items with extractions
2002/3	963,736	1,086,620		2883352
2003/4	942,940	1,061,563		2821769
2009/10	555,100	589,700	2041700	2925600
2010/11	571,300	609,300	2125100	3061900
2011/12	590,700	632,700	2190200	3164900
2012/13	589,200	629,900	2215000	3194500
2013/14	583,600	628,200	2226100	3217600
2014/15	566,900	611,500	2185500	3150500

Appendix B: Health and Social Care Information Centre Hospital Outpatient Activity data for Restorative Dentistry form 2003/4 to 2014/15 (Data for Figure 4)

Year	Attendances at first appointment in restorative dental departments in Hospital Settings (secondary care)	Attendances at subsequent appointment in restorative dental departments in Hospital Settings (secondary care)
2003/4	41,193	231,192
2004/5	63,629	243,970
2005/6	64,458	262,435
2006/7	71,245	292,695
2007/8	77,872	298,876
2008/9	78,094	293,661
2009/10	90,508	311,121
2010/11	108,483	345,221
2011/12	100,294	337,704
2012/13	100,840	328,563
2013/14	105,829	343,291
2014/15	103,026	354,653

Dentist with Special Interest (DwSI) in Endodontics

2009-11 Timetable

<table>
<tr><th>Day</th><th>Date</th><th>Teachers</th><th>Module</th></tr>
<tr><td>1</td><td>20.04.09</td><td>PB, RP, GK</td><td>Introduction
▪ Induction and Introduction to the course
▪ Agreement between teachers and trainees on the format, teaching /learning style of the course
▪ An understanding by all of the expectations of the teachers
▪ An understanding by all of the expectations of the delegates
▪ An understanding of how the in-course assessment will work and when it will take place
▪ Introduction to critical analysis of papers
▪ PM spent preparing a tooth</td></tr>
<tr><td>2</td><td>26.5.09</td><td>SE, PB</td><td rowspan="2">Module 1
▪ The structure and function of the pulp-dentine complex
▪ Pulpal reaction to bacteria, trauma and dental procedures
▪ Preservation of the pulp
▪ Diagnosis and treatment of pulpitis
▪ Access and assessment of pulpal chambers
▪ Simple restorations - Lining or not? DBA or $Ca(OH)_2$?</td></tr>
<tr><td>3</td><td>15.06.09</td><td>SE, PB</td></tr>
<tr><td>4</td><td>08.07.09</td><td>GK, PB</td><td>Module 2
▪ The scope of Endodontology
▪ Epidemiology and outcome studies for conventional root canal treatment
▪ Pathology and aetiology of apical periodontitis
▪ Diagnosis of apical periodontitis
▪ Differential diagnosis of apical periodontitis
▪ Differential diagnosis of oro-facial pain
▪ Treatment of apical periodontitis
▪ The role of antibiotics</td></tr>
<tr><td>5</td><td>14.08.09</td><td>PB</td><td rowspan="2">Module 3
▪ Case selection, treatment options and treatment planning
▪ Communicating with the patient
▪ Consent</td></tr>
<tr><td>6</td><td>16.09.09</td><td>PB</td></tr>
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<table>
<tr><td></td><td></td><td></td><td>▪ Letter writing
▪ Endodontic records and medico-legal obligations
▪ Pain control – local anaesthetic strategies
▪ Pain control – analgesia strategies
▪ Tooth restorability / Assessment of existing restorations
▪ An introduction to dismantling restorations</td></tr>
<tr><td>7</td><td>21.10.09</td><td>SE, PB</td><td rowspan="2">Module 4
▪ The objectives of endodontic treatment
▪ The preparation of the surgery
▪ The instrumentation and armamentarium
▪ Cross infection control
▪ Rubber Dam
▪ Special tests
▪ Radiology
▪ Irrigation – irrigants and chelating Agents
▪ Inter-appointment dressings</td></tr>
<tr><td>8</td><td>18.11.09</td><td>SE, PB</td></tr>
<tr><td>9</td><td>16.12.09</td><td>RP, PB</td><td rowspan="3">Module 5
▪ Tooth morphology and access cavity design
▪ Cleaning and shaping the root canal
▪ Establishing the working length
▪ Obturation of the root canal system
▪ Restoration of the root filled tooth
▪ Management of post-operative pain</td></tr>
<tr><td>10</td><td>20.01.10</td><td>RP, PB</td></tr>
<tr><td>11</td><td>17.02.10</td><td>RP, PB</td></tr>
<tr><td>12</td><td>17.03.10</td><td>PB, SD, SE</td><td>End of year 1 Assessment</td></tr>
<tr><td>13</td><td>21.04.10</td><td>PB</td><td rowspan="3">Module 6
▪ Removal of restorations
▪ Removal of root canal blockages e.g. endodontic filling material / fractured instruments cements / posts etc.
▪ Non-surgical root canal retreatment
▪ Management of calcified root canal systems</td></tr>
<tr><td>14</td><td>19.05.10</td><td>PB, SE</td></tr>
<tr><td>15</td><td>16.06.10</td><td>PB, SE</td></tr>
<tr><td>16</td><td>21.07.10</td><td>RP, PB, SE</td><td rowspan="2">Module 7
▪ Traumatic injuries to teeth
▪ Periodontic-Endodontic relationships
▪ MTA
▪ Tooth whitening for root filled teeth</td></tr>
<tr><td>17</td><td>18.08.10</td><td>RP, PB, SE</td></tr>
<tr><td>18</td><td>15.09.10</td><td>SE, PB</td><td rowspan="2">Module 8
▪ Surgical re-treatment
▪ Perforation repair
▪ Crown lengthening surgery
▪ Root resection</td></tr>
<tr><td>19</td><td>20.10.10</td><td>SE, PB</td></tr>
<tr><td>20</td><td>17.11.10</td><td>JJ, JA, PB, SE</td><td rowspan="2">Module 9
▪ Endodontic treatment for children
▪ MTA
▪ Evaluating success</td></tr>
<tr><td>21</td><td>15.12.10</td><td>JJ, JA,</td></tr>
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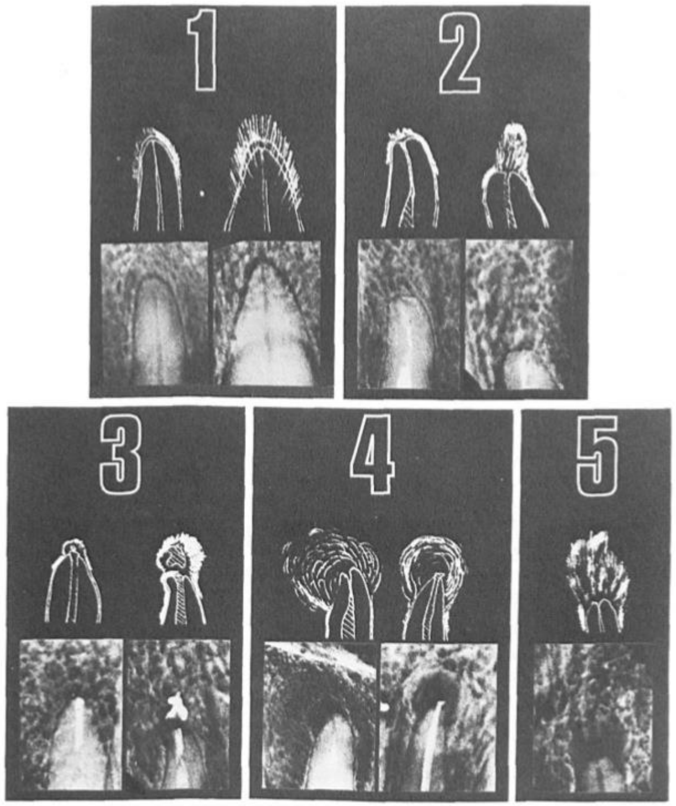
		PB, SE	▪ Managing failure
22	19.01.11	GK, PB, SE	**Module 10** ▪ Restorative implications of endodontics
23	16.02.11	PB, SE	Revision Catch up Portfolios
24	16.03.11	PB, SD, SE	**End of year 2 Assessment**
25	20.04.11	PB, RP, GK, SE	**Results and feedback**

Appendix D: Previously used scoring systems for the quality of root canal treatment, the restoration provided and healing

Study	**Scoring System**	**Method of calibration & Inter and Intra examiner reliability**	**Statistics used**
Reit & Hollander, 1983	Periapical conditions: 0 = Normal periapical conditions 1 = Increased width of the periodontal membrane space. Lamina dura continuous 2 = Increased width of the periodontal membrane space. Lamina dura diffuse 3 = Periapical radiolucency ? = Difficulties in reading the radiograph Quality of seal: A = Root filling with adequate seal in its apical 4mm D = root filling with defective seal in its apical 4mm	No calibration 3 endodontists and 3 oral radiologists 4 examiners scored all 3 months later	Alman's formula for consistency
Reit & Grondahl, 1983	Periapical classification: 1 = Periapical destruction of bone definitely not present 2 = Periapical destruction of bone probably not present 3 = Unsure 4 = Periapical destruction of bone probably present 5 = Periapical destruction of bone definitely present	No calibration 6 endodontists Intra-examiner reliability mentioned but method not described	Receiver Operating Characteristics curves
Ørstavik *et al.*,1986	Periapical Index (pictures corresponding to histological findings – steps on ordinal scale – match rad to picture and give that score). Scale of 1-5 1 = Healthy and 5 = severe periodontitis with exacerbating features	Four weeks before the second scoring, 10 difficult cases were jointly discussion and they attempted to harmonise scoring 5 endodontists, 1 dental radiologist, 4 general practitioners	Wilcoxons Man Whitney test Wilcoxons sign rank test Spearman Rank & Pearson Correlation Coefficients Arithmetic means,

	 	and 1 dental assistant All scored and repeated 2 months later	total, true and error variances, confidence intervals
Van Nieuwenhuysen *et al.,* 1994	Appearance of root filling radiographically: Bad - Short (>5 mm), or overextended (>3 mm), and/or permeable root filling Questionable - Short (3 mm < I U < 5 mm), or overextended (1mm<fill<3 mm), and/or doubtful apical seal Satisfactory - Short (1 mm<fill< 3 mm), or overextended (< 1 mm), and/or presence of a few small voids Good - < 1 mm from the radiographic apex and an apparently sound apical seal	Intra- and inter-observer agreement the radiographs were examined twice by the two observers at an interval of 1 month. The intra-observer	Wicoxon- Mann-Whitney rank sum test (and Kruskal-Wallis test) Spearman rank correlation

	Healing: Complete healing - Complete resolution of periapical radiolucency, no clinical signs and symptoms Improvement - Decrease in size of periapical radiolucency, no clinical signs and symptoms Unchanged (A) - No periapical radiolucency, clinical signs and symptoms Unchanged (B) - Persistence of periapical radiolucency, clinical signs and symptoms Deterioration - Increase in size of periapical radiolucency or occurrence of periapical radiolucency, exacerbation of clinical signs and symptoms or occurrence of clinical signs and symptoms	agreement was, respectively, 96% and 93%, Inter0observer agreement was 94% and 90%, kappa coefficient corrected agreement between the two observers was 0.74.	
Ray & Trope, 1995	Quality of root filling & restoration: 1. Good endodontic filling (GE): if all canals were obturated, no voids were present and the fill of the main gutta-percha point was within 0 to 2mm from the radiographic apex 2. Poor endodontic filling (PE): if one or more of the criteria in (1) were not met 3. Good restoration (GR): any permanent restoration that radiographically appeared sealed 4. Poor restoration (PR): any permanent restoration with radiographic signs of overhangs: open margins or recurrent decay Healing score: 1. Absence of periradicular Inflammation (API): if the contours, width and structure of the periodontal ligament were normal or slightly widened if an excess of filling material was present 2. Presence of periradicular inflammation (PPI): if one or more of the criteria of success were not fulfilled	2 independent examiners no mention of training, calibration or Kappa scoring	Chi^2 Odds ratio Mantel-Haenszel statistic
Tronstad *et al.*, 2000	Quality of root filling: Good endodontics (all canals obturated, no voids present, root filling ending between 2 mm short of and 1 mm beyond radiographic apex) or Poor endodontics (root filling ending more than 2 mm from radiographic apex, root filling with voids or canals not filled, root filling poorly dimensioned or poorly condensed) Quality of restoration: Good restoration (any permanent restoration that appeared intact radiographically) or Poor restoration (any permanent restoration with radiographic signs of overhangs, recurrent decay or open margins) Success/Failure: Success (normal width of periodontal ligament space, normal appearance of	2 examiners independently Trained and calibrated using 47 roots Disagreement was dealt with by joint discussion. If consensus was not	Chi^2

	surrounding bone) or Failure (periradicular radiolucency) Multi-rooted teeth were categorized by the root with the most incomplete root filling	reached, the third observer made the final decision. Intra-examiner reliability – 44 roots rescored	
Kirkevang *et al.*, 2000	Coronal restorations (filling and crown): 1 = Adequate (radiographically sealed) 2 = Inadequate (radiographic signs of overhangs or with open margins) Lateral seal of root filling: 1 = Adequate in the coronal 1/2 of the root filling + adequate in the apical 1/2 of the root filling 2 = Adequate in the coronal 1/2 of the root filling + inadequate in the apical 1/2 of the root filling 3 = Inadequate in the coronal 1/2 of the root filling + adequate in the apical 1/2 of the root filling 4 = Inadequate in the coronal 1/2 of the root filling + inadequate in the apical 1/2 of the root filling Length of root filling: 1 = Root filling ending ≤3 mm from radiographic apex 2 = Root filling ending >3 mm from radiographic apex 3 = Pulpotomy, material seen only in the pulp chamber 4 = Flush, root filling ending at the radiographic apex 5 = Over-filling, root filling material seen in the periapical area Periapical index (PAI) (Ørstavik et al. 1986): 1 = Normal periapical structures 2 = Small changes in bone structure 3 = Changes in bone structure with some mineral loss 4 = Periodontitis with well-defined radiolucent area 5 = Severe periodontitis with exacerbating features	1 examiner scored all 773 teeth Calibrated for PAI scoring using 100 reference teeth 60 radiographs rescored for intra examiner reliability Kappa scored	Chi^2 test to evaluate differences between subgroups of teeth
Hommez *et al.*, 2002	Clinical coronal status: 1. Good margin (acceptable)	2 examiners Calibrated at the	Chi^2 & Odds ratio for differences

	2. Catching of the explorer, no visible crevice (acceptable) 3. Crevice limited to the enamel (acceptable) 4. Crevice penetrating the dentine (unacceptable) 5. Fracture of restoration (unacceptable) 6. Detached restoration (unacceptable) 7. Lost restoration (unacceptable) Marginal decay Crown or filling Radiographic coronal status: 1. Intact restoration without signs of leakage (acceptable) 2. Restoration with open margin (unacceptable) 3. Restoration with recurrent decay (unacceptable) Presence or absence of a base under the restoration Amalgam or composite Presence of a post in the root canal Length of the root filling: 1. Root filling terminating 0-2 mm from the radiographic apex (acceptable) 2. Root filling terminating >2 mm from the radiographic apex (unacceptable) 3. Root filling extending beyond the radiographic apex (unacceptable) Homogeneity of the root filling: 1. Homogeneous root filling, good condensation, no voids visible (acceptable) 2. Inhomogeneous root filling, poor condensation, voids visible Periapical status: 1. Normal: good periapical condition	beginning and at regular intervals Inter examiner reliability – 51 teeth double scored Kappa scored Then at each time only scored by one examiner as inter examiner Kappa scores were high	between groups Multivariate logistic regression Spearman's r_s for correlation between rad and clinical findings

	2.Widening of the periodontal ligament not exceeding two times the width of the lateral periodontal ligament 3. Periapical radiolucency in connection with the apical part of the root, exceeding at least two times the width of the lateral periodontal ligament Only root-canal fillings terminating 0-2 mm from the radiographic apex and homogeneous were listed acceptable For multi-rooted teeth the root with the most severe periapical condition was used		
Boucher *et al.,* 2002	A PAI score greater than 2 was considered a sign of periapical pathology (Ørstavik 1986). A filling without any voids or defects along the walls of the canal and located between 0 and 2 mm from the radiographic apex, was considered to be an acceptable filling. Each root was scored as acceptable or unacceptable Presence/absence of root filling, quality of root filling, coronal restorations and presence/absence of post were correlated with periapical scores	4 examiners in groups of two (3 members of the Restorative Dentistry and Endodontics depts. + 1 endodontics trainee - resident) Calibrated in 2 sessions 1 month apart, prior to assessment All rads assessed within 2 months	Chi^2
Segura-Egea *et al.,* 2004	Coronal restorations (filling and crown): 1 = Adequate (radiographically sealed) 2 = Inadequate (radiographic signs of overhangs or with open margins) Lateral seal of root filling: 1 = Adequate in the coronal 1/2 of the root filling + adequate in the apical 1/2 of the root filling 2 = Adequate in the coronal 1/2 of the root filling + inadequate in the apical 1/2 of the root filling 3 = Inadequate in the coronal 1/2 of the root filling + adequate in the apical 1/2 of the root filling 4 = Inadequate in the coronal 1/2 of the root filling + inadequate in the apical 1/2 of the root filling Length of root filling:	1 experienced endodontist Calibrated for PAI using 100 radiographs – before both examination and re-examination Intra-examiner reliability assessed	Logistic regression and odds ratios

	1 = Root filling ending ≤3 mm from radiographic apex 2 = Root filling ending >3 mm from radiographic apex 3 = Pulpotomy, material seen only in the pulp chamber 4 = Flush, root filling ending at the radiographic apex 5 = Over-filling, root filling material seen in the periapical area Periapical index (PAI) (Ørstavik et al. 1986): 1 = Normal periapical structures 2 = Small changes in bone structure 3 = Changes in bone structure with some mineral loss 4 = Periodontitis with well-defined radiolucent area 5 = Severe periodontitis with exacerbating features	using 50 of the radiographs scored a second time Kappa scored	
Van de Sluis *et al.,* 2005	Extracted human teeth, root filled and radiographed after extraction: 1 = Well-condensed gutta-percha which filled the entire prepared root canal, was well adapted to the canal wall and showed only a few, minor air bubbles (less than 0.25mm in diameter) or separate gutta-percha cones only at the cervical level. 2 = An imperfectly condensed filling that might be a little short (0.5 mm or less), and that might show irregularities of less than 1mm in the adaptation. 3 = Inadequately, condensed gutta-percha with irregularities of less than 2 mm, a filling that might be 1.5 mm short and/or might show separate gutta-percha cones in the coronal half of the root canal. 4 = Poorly condensed gutta-percha with irregularities of more than 2 mm, a filling that might be more than 2mm short and/or might show separate gutta-percha cones in the apical half of the root canal. The fluid transport along the root filings was measured Then the teeth were sectioned and quality of root filling assessed	3 examiners randomly and independently scored Examiners were trained and calibrated – not described how	T test Mann Whitney U test
Loftus *et al.,* 2005	Panoramic radiographs assessed: PAI score >3 regarded as apical periodontitis (Orstavik 1986) Multi-rooted teeth given the score of the root with the most severe score	2 examiners calibrated using 15 OPGs	Chi^2

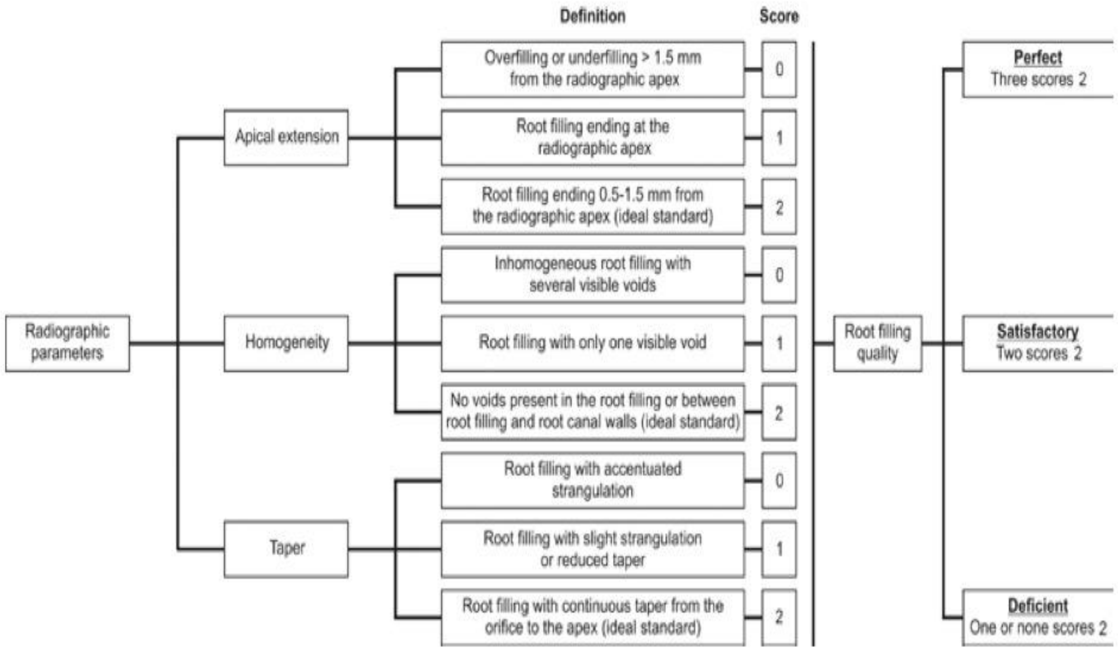
	Quality of root fillings sored using European Society of Endodontology guidelines (1994): Adequate: well filled root canal, without visible voids contained within the tooth and ending no less than 2 mm from the radiographic apex Inadequate: root treatment was under filled, overfilled or poorly condensed		
Eleftheriadis & Lambrianidis, 2005	Quality of root fillings: A length of <2 mm from the apex with no voids ('Acceptable' filling): filling ending 0–2 mm short of the apex with uniform radio density and adaptation of the filling to the root canal walls Overfilling with no voids: filling extruding beyond the apex with uniform radio density and adaptation of the filling to the root canal walls. A length of >2 mm from the apex with no voids: filling ending more than 2 mm from the radiographic apex with uniform radio density and adaptation of the filling to the root canal walls. A length of <2 mm from the apex with voids: filling ending 0–2-mm short of the apex with visible canal space laterally along the filling or voids within the filling mass. Overfilling with voids: filling extruding beyond the apex with visible canal space laterally along the filling or voids within the filling mass. A length of >2 mm from the apex with voids: filling ending more than 2 mm from the radiographic apex with visible canal space laterally along the filling or voids within the filling mass. Detection of iatrogenic errors: Ledge formation was diagnosed when the root filling was at least 1 mm shorter than the initial working length or deviated from the original canal shape in teeth where root canal curvature occurred. Furcation perforation was diagnosed when extrusion of filling material through the furcation area was detected in multi-rooted teeth. Strip perforation was diagnosed when extrusion of filling material was detected in the lateral (inner) wall of mesiobuccal roots of maxillary molars, mesial roots of mandibular molars and in any root of other teeth. Root perforation was diagnosed when extrusion of filling material was detected in any other area of a root except the furcation area and the lateral wall of the root.	2 examiners calibrated using 50 radiographs from the main study If disagreement, the examiners came to a consensus Intra examiner scoring of 50 randomly selected rads 2 months after initial scoring Kappa scored	Chi^2

	Presence of a fractured instrument was diagnosed when a fractured instrument was detected inside a root canal or with its tip extending into the periapical area.		
Lynch & Burke, 2006	Root filling as seen radiographically assessed as: Adequate = where the root canal filling was within 2 mm of the radiographic apex Under-filled = where the root canal filling was >2 mm from the radiographic apex Over-filled = where the root canal filling was extruded beyond the radiographic apex The presence of voids, fractured instruments, and root perforations were noted	Not stated	Logistic regression
Molander *et al.,* 2007	Score for quality of root filling (JPEG of scanned rads): 1: Correct length, adequate seal, tapered preparation, no transport. 2: Correct length, adequate seal, lack of taper and/or transport. 3: Incorrect length, adequate seal, (taper and transport not evaluated). 4: Correct length, defective seal, (taper and transport not evaluated). 5: Incorrect length, defective seal, (taper and transport not evaluated). Assessment criteria: Length of the root filling correct if it terminated within 2.5 mm short of the apex of the root. Cases with surplus of sealer material: correct length if the apical stop preparation was placed within the accepted distance from the apex. Quality of seal was assessed in the apical two-third of the canal Ideal root canal preparation should be tapered (roughly corresponding to 0.06) and without signs of canal transportation (zipping or stripping) In multi-rooted teeth only highest score was used in analyses	Two examiners scored simultaneously using 17inch screen Rescored 114 roots after 1 year with Kappa 0f 0.66 for the 5 point scale No mention of training or calibration, films were scanned and stored as JPEGs	T test
Bierenkrant *et al.,* 2008	1. Density: Homogenous, Non homogenous, Adequate, Low For the statistical analysis, divided into variable 1 (homogenous versus non-homogenous) and variable 2 (adequate versus low). Variable 1 was based on the uniformity of the root filling density. Variable 2 was based on the radio-density of the root filling. 2. Taper: Smooth and continuous, Irregular, Excessive, Absent Taper was based on the contours of the root filling measured from radiographic apex to its coronal extent	3 endodontists – calibrated, blinded, independently assessed Calibration using scoring 35 randomly selected sample of cases which were not	Generalised linear mixed model

	3. Lateral adaptation: No lumen lateral to the root filling, Adequate, Inadequate 4. Extrusion (sealer): None, Small, Large No and/or small extrusion of sealer only was deemed adequate. Large sealer extrusion was assigned when its diameter 2+ mm 5. Lateral canals: number 6. Apical enlargement: Small, Appropriate, Excessive The apical 1–2 mm of the root filling was assessed and the extent of enlargement was assigned based on its dimension relative to the root morphology. 7. Transportation: None, Moderate, Severe No transportation – The root filling followed the natural contour of the root filling. Moderate/severe transportation – The root filling tended to straighten relative to the natural contour of the root outline. Results dichotomized (Molander 2007): Adequate: Correct length (within 2mm of radiographic apex), adequate lateral adaptation of the root filling to the canal walls, smooth and continuous taper, and no transportation. Inadequate: Correct length (within 2mm of radiographic apex), adequate lateral adaptation of the root filling to the canal walls, lack of taper and/or transportation.	part of the study Disagreements resolved by reaching a consensus	
Frisk *et al.,* 2008	Adequate seal: No voids lateral or apical to the root filling and the root filling should appear homogenous Length: Distance between the root filling and radiographic apex measured on a scale to the nearest 0.1 mm Periapical index score (Ørstavik et al. 1986): 1. Normal periapical structure 2. Small changes in bone structure 3. Changes in bone structure with some mineral loss 4. Periodontitis with well-defined radiolucent area 5. Severe periodontitis with exacerbating features In multi-rooted teeth the root with the highest score was used PAI score dichotomized to 1-2 = healthy and 3-5 = disease	1 examiner Calibrated for PAI using 100 radiographs Calibrated for quality of root filling against another of the authors Intra examiner reliability by scoring 67 rads after 7 months Kappa scored	Chi^2 for association between quality of root filling and periapical status Kruskal-Wallis test for differences in means Multivariate logistic regression analyses for independent

			variables quality of root filling (adequate/inadequate), age, gender, type of tooth and dependent variable PAI score (0=PAI score 1-2 and 1=PAI score 3-5)
Kayahan *et al.,* 2008	Quality of root filling (from panoramic radiograph): Good Endodontic treatment: All canals obturated without voids. Root canal filling between 2 mm short or maximum 1 mm beyond radiographic apex. Poor Endodontic treatment: Root canal filling ending more than 2 mm short of the radiographic apex or grossly overfilled. Root canal filling with inadequate density, voids, unfilled canals, or poor condensation. PAI Score (Ørstavik et al. 1986): 1. Normal periapical structures 2. Small changes in bone structure 3. Changes in the bone structure with little mineral loss 4. Periodontitis with well-defined radiolucent area 5. Severe periodontitis with exacerbating features PAI of 1 deemed healthy and PAI 2-5 deemed disease	1 endodontist and 1 prosthodontist Calibrated using 200 teeth If disagreement 3rd examiner made decision Kappa scored	Chi^2 test
Moussa-Badran *et al.,* 2008	Quality of root fillings: 1. Presence or absence of a low density of root canal filling. 2. Presence or absence of voids in the root filling or between root filling and root canal walls. 3. Presence or absence of a 'under filling': the root canal filling material is >2 mm short of the radio- graphical apex. 4. Presence or absence of a 'overfilling': the root canal filling material is extruded beyond the	2 examiners if disagreement 3rd examiner involved to reach final agreement	

	radio- graphical apex. Each parameter scored with 0 = absence (criterion not observed on the radiographs) or 1 = presence (criterion observed on the radiographs). For a multi-rooted tooth, each root canal was independently evaluated, scored, and then an overall score was attributed (e.g. when the same parameter was observed on several root canals, the score '1' was attributed only once for the entire tooth). The scores of each parameter were added up to obtain a final score allowing the assessment of the technical quality of the root filling. Final score 0 = adequate root filling deemed adequate Final score of 4 = under- or over-filled canal		
Tavares *et al.*, 2009	Quality of root filling score: Adequate: All canals obturated. No voids present. Root canal fillings end from 0–2 mm short of the radiographic apex. Inadequate: Root canal fillings end more than 2 mm short of the radiographic apex or grossly overfilled. Root canal fillings with voids, inadequate density, unfilled canals, and/or poor condensation. Quality of coronal restoration score: Adequate: Any permanent restoration that appeared intact radio- graphically. Inadequate: Any permanent restoration with detectable radio- graphic signs of overhangs, open margins or recurrent caries, or presence of temporary coronal restoration. Teeth with no coronal restorations, permanent or temporary, were also included in this group. Healing outcome using PAI score and Strindberg criteria: PAI 1 (normal periradicular structures) PAI 2 (small changes in bone structure) PAI 3 (changes in bone structure with some mineral loss) PAI 4 (periodontitis with well-defined radiolucent area) PAI 5 (severe periodontitis with elements indicating expansion of the lesion) Strindberg healthy: no radiographically discernible periradicular changes except for widened periodontal ligament	2 examiners – calibrated using 100 rads 3rd endodontist involved where there was disagreement	Chi^2 Fischer's Exact test

	Strindberg diseased: any discernible apical radiolucency Worst score of all canals carried forward for multi-rooted teeth.		
Santos *et al.*, 2010		2 professors and 1 endodontic resident In case of disagreement, the 3 examiners came to a consensus. Kappa scored	Pearson's chi-square test to compare the results among root canal groups. Mann-Whitney and Fisher's Exact for frequency score of quality parameters of the root canal groups Odds ratio (OR) and 95% confidence interval (CI) for association among complicating factors and standard filling quality
Unal *et al.,* 2011	Technical quality of the root fillings: Length of the root filling: 1. Root filling terminating 0-2 mm from the radiographic apex (acceptable). 2. Root filling terminating >2 mm from the radiographic apex (unacceptable). 3. Root filling extending beyond the radiographic apex (unacceptable). Homogeneity of the root filling: 1. Homogeneous root filling, good condensation, no voids visible (acceptable).	2 endodontists and 1 doctorate student If disagreement consensus reached Trained and calibrated using 75 radiographs before both	Chi^2 - differences between the technical qualities of the root canal treatment according to the tooth type and clinical experience

	2. Inhomogeneous root filling, poor condensation, voids visible (unacceptable).	examinations Intra examiner reliability using 75 rads scored 2 months later Kappa scored	of dental students
Fonseka *et al.*, 2013	Quality of root filling: 1. Length: Acceptable (obturation within 2mm of the radiographic apex) or Not Acceptable (obturation short by more than 2mm of radiographic apex or obturation beyond the apex) 2. Homogeneity: Acceptable (radiopacity of the obturation material uniform, well condensed and no voids) or Not Acceptable (non-uniform radio-opacity, poorly condensed and presence of voids 3. Taper: Acceptable (well tapered preparation and obturation) or Non Acceptable (poorly tapered preparation and obturation)	3 examiners Calibrated using 10 rads not from the study – Kappa scored	Chi^2
Dahlström *et al.*, 2011	Quality of root filling in each root (if more than one root only the highest score taken into account), assessing length (within 2.5mm of radiographic apex, surplus sealer considered correct length), seal, taper and canal transportation: Score 1: correct length, good seal, tapered canal, no transportation Score 2: correct length, good seal, taper lacking, and/or transportation Score 3: incorrect length, good seal (taper and transportation not evaluated) Score 4: correct length, poor seal (taper and transportation not evaluated) Score 5: incorrect length, poor seal (taper and transportation not evaluated)	Four molar teeth from each dentist (after training) Cases in random order, analysed together by 2 examiners and aimed to reach consensus (if not 3rd examiner called in) Analysed on a 17 inch screens and did adjust the brightness, contrast, and image size if needed Plain films scanned in a Dimage Scan Dual IV (Konica Minolta	Pearson's Chi^2 test using a 95% confidence interval Kappa score for intra examiner reliability only (50 roots re-evaluated after 1 month, Intra-observer agreement reached kappa 0.85)

		Photo Imaging), using Dimage 1.0.2 software, and stored in Photoshop (Adobe Systems, Seattle, WA, USA) as JPEG images.	
Koch *et al.,* 2013	Periapical status (PAI, Periapical Index): PAI score 1 (normal periapical structures), PAI score 2 (small changes in bone structure), PAI score 3 (changes in bone structure with some mineral loss), PAI score 4 (periodontitis with well-defined radiolucent area) or PAI score 5 (severe periodontitis with exacerbating features) Root filling quality: 1. Density: Adequate density (no visible voids lateral to the root filling) or Inadequate density (visible voids lateral to the root filling) 2. Length: Adequate length (root filling ending ≤2 mm from radiographic apex), Short (root filling ending >2 mm from radiographic apex) or Overfilled (root filling material in the periodontal membrane space) 3. Marginal bone loss (root length = from the cemento-enamel junction to the apex of the root): Marginal bone loss <1/3 of the root length or Marginal bone loss ≥1/3 of the root length or Not assessable 4. Coronal restoration: Laboratory produced crown, Direct composite restoration, Temporary restoration, No coronal restoration, Other (laboratory produced crown + filling) or Not assessable 5. Quality of the restoration: Adequate (complete restoration with no visible under-extension or gap), Inadequate (incomplete restoration or visible under-extension or gap), No restoration or Not assessable Outcome was overall tooth survival (tooth still present) and success (PAI 1 + 2)	Power calculation for 10% change in presence of apical areas before and after training 830 root filled teeth (414 in 2002 and 416 in 2005) In 16 clinics, radiographs were taken using conventional (analogue) film Kodak Insight" (Eastman Kodak Co., Rochester, NY, USA): digital radiography (DentalEye", Sundbyberg, Sweden) was used in two clinics. All analogue films were retrieved in the original. The digital	Descriptive, independent Pear-son's chi-square and Fisher's exact test in cases of expected values <5 Agreement of 89.6% of all observations. Kappa values for inter-observer agreements on treatment and follow-up data were 0.73 and 0.75 for the PAI scores, 0.81 and 0.84 for the density of root fillings and 0.87 and 0.89 for the apex-distance

		radiographs were copied to CD-ROMs or USB-flash drives 2 calibrated Endodontists independently assessed radiographs. Final consensus after discussion or with 3rd examiner	observations
Dahlström *et al.,* 2015	Quality of root filling in each root (if more than one root only the highest score taken into account), assessing length (within 2.5mm of radiographic apex, surplus sealer considered correct length), seal, taper and canal transportation: Score 1: correct length, good seal, tapered canal, no transportation Score 2: correct length, good seal, taper lacking and/or transportation Score 3: incorrect length, good seal (taper and transportation not evaluated) Score 4: correct length, poor seal (taper and transportation not evaluated) Score 5: incorrect length, poor seal (taper and transportation not evaluated)	Two molar teeth from each dentist (just before training and 6months after training) Cases in random order, analysed simultaneously by 2 examiners on a 17 inch screen Plain films scanned in a Dimage Scan Dual IV (Konica Minolta Photo Imaging), using Dimage 1.0.2 software, and stored in Photoshop (Adobe Systems, Seattle, WA, USA) as JPEG images	Pearson's Chi^2 test using a 95% confidence interval Inter and intra examiner reliability not mentioned
Azim *et al.,* 2016	Apical extension of Gutta-percha in relation to the radiographic apex: >2 mm short of the radiographic apex	Two clinicians – endodontic faculty	

	1–2 mm short of the radiographic apex Within 0.5 mm short of the radiographic apex Overextended Voids in the obturation: present or absent Density of the root filling: Good: homogeneous radiopaque material with no visible space between the material and the walls of the canal and with no more than 2 small voids (<1 mm) along the entire root filling. Poor: non-uniform radio-density, with multiple voids along the root filling and/or canal space visible laterally and apically Procedural error (present or absent): procedural errors included missed canals, perforations, fractured instrument(s) and/or apical transportation identified through periapical radiographs. Radiographic healing: Healed: complete healing i.e. absence of a periapical lesion with no pain, swelling or discomfort Healing: incomplete healing i.e. reduction in the size of the periapical lesion but not completely resolved with no pain, swelling or discomfort Not healing: no change in the size of the periapical lesion/increase in the size of the periapical lesion/development of a new periapical lesion/ development of clinical signs or symptoms (pain, swelling or discomfort) further divided into: a. Uncertain healing: no change in the size of the periapical lesion, with no clinical signs or symptoms (pain, swelling or discomfort). b. Unsatisfactory healing: presence of any of the following conditions: development of a new periapical lesion, existing periapical lesion increased in size, presence of signs or symptoms (pain, swelling or discomfort)	member and dental student assessed radiographs – no mention of training, calibration or inter/intra examiner reliability Statistical analysis was univariate, bivariate and multivariate	

Appendix E: Mind map of the scope of the study

Appendix F: Search strategy used for MEDLINE and EMBASE

Database: Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations and Ovid MEDLINE(R) <1946 to Present>
Search Strategy:
----
1 Education, Dental, Graduate/ (1796)
2 (Dentist* or Dental).tw. (213659)
3 (postgraduate* or graduate* or post-graduate* or "post graduate*").tw. (46116)
4 (train* or Learn* or Educat*).tw. (949665)
5 3 or 4 (965837)
6 2 and 5 (21573)
7 1 or 6 (22573)
8 (skill* or Competent* or Competence*).tw. (206602)
9 exp Clinical Competence/ (73794)
10 8 or 9 (258697)
11 7 and 10 (2914)
12 ("Primary care" or "Dental Practice*").tw. (91397)
13 exp General Practice, Dental/ or exp Dental Health Services/ (37941)
14 exp Dental Care/ and exp Primary Health Care/ (714)
15 12 or 13 or 14 (126714)
16 11 and 15 (763)
17 Outcome*.tw. (1142769)
18 exp Treatment Outcome/ or exp Patient Outcome Assessment/ or exp "Outcome Assessment (Health Care)"/ or exp "Outcome and Process Assessment (Health Care)"/ (846604)
19 17 or 18 (1690233)
20 11 and 19 (422)
21 16 and 19 (107)
22 ("root canal*" or "root filling*" or endodont*).tw. (24713)
23 exp "Root Canal Therapy"/ (18341)
24 22 or 23 (30471)
25 11 and 24 (83)
26 11 and 15 and 19 and 24 (7)

Database: Embase Classic+Embase <1947 to 2016 June 21>
Search Strategy:
----
1 Education, Dental, Graduate/ (21055)
2 (Dentist* or Dental).tw. (227030)
3 (postgraduate* or graduate* or post-graduate* or "post graduate*").tw. (60677)

4 (train* or Learn* or Educat*).tw. (1251516)

5 3 or 4 (1274274)

6 2 and 5 (22833)

7 1 or 6 (36587)

8 (skill* or Competent* or Competence*).tw. (269130)

9 exp Clinical Competence/ (48163)

10 8 or 9 (303359)

11 7 and 10 (3687)

12 ("Primary care" or "Dental Practice*").tw. (116334)

13 exp General Practice, Dental/ or exp Dental Health Services/ (301534)

14 exp Dental Care/ and exp Primary Health Care/ (539)

15 12 or 13 or 14 (404262)

16 11 and 15 (1450)

17 Outcome*.tw. (1621834)

18 exp Treatment Outcome/ or exp Patient Outcome Assessment/ or exp "Outcome Assessment (Health Care)"/ or exp "Outcome and Process Assessment (Health Care)"/ (1167420)

19 17 or 18 (2303108)

20 11 and 19 (451)

21 16 and 19 (210)

22 ("root canal*" or "root filling*" or endodont*).tw. (23497)

23 exp "Root Canal Therapy"/ (26708)

24 22 or 23 (35680)

25 11 and 24 (132)

26 11 and 15 and 19 and 24 (23)

Hand Searches (4)

Appendix G: Search findings (Citation)

<u>Database: Embase Classic+Embase <1947 to 2016 June 21> 23 papers</u>

1. Sanchez-Sanhueza G., Cisterna Cabrera F. Praxis teaching in the ambit of learning assessment of endodontics in a Chilean university. Brazilian oral research. 29 (1) (pp 1-6), 2015.

2. Suebnukarn S., Chaisombat M., Kongpunwijit T., Rhienmora P. Construct validity and expert benchmarking of the haptic virtual reality dental simulator. Journal of dental education. 78 (10) (pp 1442-1450), 2014.

3. Koch M. On implementation of an endodontic program. Swedish dental journal. Supplement. (230) (pp 9-97), 2013.

4. Friedlander L., Anderson V. A new predoctoral endodontic module: evaluating learning and effectiveness. Journal of dental education. 75 (3) (pp 351-359), 2011.

5. Alani A., Bishop K., Djemal S. The influence of specialty training, experience, discussion and reflection on decision making in modern restorative treatment planning. British Dental Journal. 210 (4) (pp E4), 2011.

6. Virdi M.S., Sood M. Effectiveness of a five-step method for teaching clinical skills to students in a dental college in India. Journal of dental education. 75 (11) (pp 1502-1506), 2011.

7. Dahlstrom L., Molander A., Reit C. Introducing nickel-titanium rotary instrumentation in a public dental service: The long-term effect on root filling quality. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology. 112 (6) (pp 814-819), 2011.

8. Zhao Y., Gong Y. Knowledge of emergency management of avulsed teeth: a survey of dentists in Beijing, China. Dental traumatology : official publication of International Association for Dental Traumatology. 26 (3) (pp 281-284), 2010.

9. Connor J.P., Hendricson W.D., Guest G.F., Dodge W.W. Development and implementation of an online screening application at the University of Texas Health Science Center at San Antonio Dental School. Journal of dental education. 74 (11) (pp 1206-1213), 2010.

10. Jordan R.A., Gaengler P., Markovic L., Zimmer S. Performance of Atraumatic Restorative Treatment (ART) depending on operator-experience. Journal of Public Health Dentistry. 70 (3) (pp 176-180), 2010.

11. Al-Jewair T.S., Qutub A.F., Malkhassian G., Dempster L.J. A systematic review of computer-assisted learning in endodontics education. Journal of dental education. 74 (6) (pp 601-611), 2010.

12. Wright E.F., Hendricson W.D. Evaluation of a 3-D interactive tooth atlas by dental students in dental anatomy and endodontics courses. Journal of dental education. 74 (2) (pp 110-122), 2010.

13. Smith M., Lennon M.A., Robinson P.G. Students' clinical experience on outreach placements. European Journal of Dental Education. 14 (1) (pp 7-11), 2010.

14. Suebnukarn S., Haddawy P., Rhienmora P., Gajananan K. Haptic Virtual Reality for Skill Acquisition in Endodontics. Journal of Endodontics. 36 (1) (pp 53-55), 2010.

15. Pileggi R., O'Neill P.N. Team-based learning using an audience response system: an innovative method of teaching diagnosis to undergraduate dental students. Journal of dental education. 72 (10) (pp 1182-1188), 2008.

16. Arena G., Kruger E., Holley D., Millar S., Tennant M. Western Australian dental graduates' perception of preparedness to practice: a five-year follow-up. Journal of dental education. 71 (9) (pp 1217-1222), 2007.

17. Sukotjo C., Thammasitboon K., Howell H., Karimbux N. The impact of targeted shortened preclinical exercises on student perceptions and outcomes. Journal of dental education. 71 (8) (pp 1070-1079), 2007.

18. Lynch C.D., Burke F.M. Quality of root canal fillings performed by undergraduate dental students on single-rooted teeth. European journal of dental education : official journal of the Association for Dental Education in Europe. 10 (2) (pp 67-72), 2006.

19. De Quadros I., Gomes B.P., Zaia A.A., Ferraz C.C., Souza-Filho F.J. Evaluation of endodontic treatments performed by students in a Brazilian Dental School. Journal of dental education. 69 (10) (pp 1161-1170), 2005.

20. Helminen S.E., Vehkalahti M., Murtomaa H. Dentists' perception of their treatment practices versus documented evidence. International dental journal. 52 (2) (pp 71-74), 2002.

21. Dugas N.N., Lawrence H.P., Teplitsky P., Friedman S. Quality of life and satisfaction outcomes of endodontic treatment. Journal of endodontics. 28 (12) (pp 819-827), 2002.

22. Maggs-Rapport F.L., Treasure E.T., Chadwick B.L. Community dental officers' use and knowledge of restorative techniques for primary molars: an audit of two Trusts in Wales. International journal of paediatric dentistry / the British Paedodontic Society [and] the International Association of Dentistry for Children. 10 (2) (pp 133-139), 2000.

23. Mayhew R.B., Svee T.A., Johnson C.W., Markins S.R. Quality of obturation in student cases instructed by endodontic versus general dentistry faculty. Journal of endodontics. 25 (6) (pp 461-463), 1999.

Database: Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations and Ovid MEDLINE(R) <1946 to Present> 7 papers

1. Koch M. On implementation of an endodontic program. Swedish Dental Journal - Supplement. (230)9-97, 2013.

2. Dahlstrom L; Molander A; Reit C. Introducing nickel-titanium rotary instrumentation in a public dental service: the long-term effect on root filling quality. Oral Surgery Oral Medicine Oral Pathology Oral Radiology & Endodontics. 112(6):814-9, 2011 Dec.

3. Alani A; Bishop K; Djemal S. The influence of specialty training, experience, discussion and reflection on decision making in modern restorative treatment planning. British Dental Journal. 210(4):E4, 2011 Feb 26.

4. Smith M; Lennon MA; Robinson PG. Students' clinical experience on outreach placements. European Journal of Dental Education. 14(1):7-11, 2010 Feb.

5. Dugas NN; Lawrence HP; Teplitsky P; Friedman S.Quality of life and satisfaction outcomes of endodontic treatment. Journal of Endodontics. 28(12):819-27, 2002 Dec.

6. Helminen SE; Vehkalahti M; Murtomaa H. Dentists' perception of their treatment practices versus documented evidence. International Dental Journal. 52(2):71-4, 2002 Apr.

7. Mayhew RB; Svee TA; Johnson CW; Markins SR. Quality of obturation in student cases instructed by endodontic versus general dentistry faculty. Journal of Endodontics. 25(6):461-3, 1999 Jun.

<u>Hand search 5 papers</u>

1. Dahlström L, Molander A, Reit C (2015) The impact of a continuing education programme on the adoption of nickel-titanium rotary instrumentation and root-filling quality amongst a group of Swedish general dental practitioners. European Journal of Dental Education 19, 23-30.
2. Molander A, Caplan D, Bergenholtz G, Reit C. Improved quality of root fillings provided by general dental practitioners educated in nickel–titanium rotary instrumentation. International Endodontic Journal, 40, 254–260, 2007.
3. Reit C, Bergenholtz G, Caplan D, Molander A. The effect of educational intervention on the adoption of nickel–titanium rotary instrumentation in a Public Dental Service. International Endodontic Journal, 40, 268–274, 2007.
4. Koch M, Eriksson HG, Axelsson S, Tegelberg A. Effect of educational intervention on adoption of new endodontic technology by general dental practitioners: a questionnaire survey. International Endodontic Journal, 42, 313–321, 2009.
5. Koch M, Wolf E, Tegelberg A, Petersson K. Effect of education intervention on the quality and long-term outcomes of root canal treatment in general practice. *International Endodontic Journal* 2015; **48**, 680-9.

Appendix H: Ethical Approval

NHS

National Research Ethics Service

Central London REC 1
Level 7N019, Maternity Block
Northwick Park Hospital
Watford Road
Harrow
Middx
HA1 3UJ

Telephone: 020 8869 3775
Facsimile: 020 8869 5222

08 October 2010

Dr Jennifer Gallagher
Dental Public Health
King's College London Dental Institute
Denmark Hill
Caldecot Road
London
SE5 9RW

Dear Dr Gallagher

Study Title:	**Exploring the relationship between the quality of care provided by general dental practitioners with a special interest in Endodontics and the clinical, radiographic and patient related outcome of endodontic treatment**
REC reference number:	**10/H0718/69**

The Research Ethics Committee reviewed the above application at the meeting held on 29 September 2010. Thank you for attending to discuss the study.

Ethical opinion

The Committee reviewed the above study. The Chief Investigator Dr Jennifer Gallagher attended to discuss the application; the Chair informed Dr Gallagher who was waiting in the adjoining room that her study had been approved.

The members of the Committee present gave a favourable ethical opinion of the above research on the basis described in the application form, protocol and supporting documentation, subject to the conditions specified below.

Ethical review of research sites

The favourable opinion applies to all NHS sites taking part in the study, subject to management permission being obtained from the NHS/HSC R&D office prior to the start of the study (see "Conditions of the favourable opinion" below).

Conditions of the favourable opinion

The favourable opinion is subject to the following conditions being met prior to the start of the study.

<u>Management permission or approval must be obtained from each host organisation prior to the start of the study at the site concerned</u>.

For NHS research sites only, management permission for research ("R&D approval") should be obtained from the relevant care organisation(s) in accordance with NHS research governance arrangements. Guidance on applying for NHS permission for research is available in the Integrated Research Application System or at http://www.rdforum.nhs.uk. Where the only involvement of the NHS organisation is as a Participant Identification Centre, management permission for research is not required but the R&D office should be notified of the study.

Guidance should be sought from the R&D office where necessary.

Sponsors are not required to notify the Committee of approvals from host organisations.

It is responsibility of the sponsor to ensure that all the conditions are complied with before the start of the study or its initiation at a particular site (as applicable).

Approved documents

The documents reviewed and approved at the meeting were:

Document	*Version*	*Date*
Investigator CV		01 January 2007
Protocol	6	26 August 2010
No opinion letter from South East London REC 3		13 August 2010
DwSI information sheet	6	26 August 2010
Form for patient follow up assessment at 12 months post completion of endodontic treatment	6	26 August 2010
Tracking patients enrolled in the research project	6	26 August 2010
REC application		07 September 2010
Covering Letter		07 September 2010
Participant Information Sheet	6	26 August 2010
Participant Information Sheet: for principals of the practice DwSI is working in	6	
Participant Consent Form		26 August 2010
Participant Consent Form: for principals (for DwSI & patients taking part in this research project)	6	26 August 2010
Questionnaire: Patient questionnaire before treatment	6	26 August 2010
Questionnaire: Patient questionnaire after treatment	6	26 August 2010
Questionnaire: Patient questionnaire at 12 month review	6	26 August 2010
Questionnaire: DwSI	6	26 August 2010
DwSI consent form for participation in evaluation study	6	26 August 2010
Assessment of 12 month review radiograph	6	26 August 2010
Retro assessment of DwSI's endodontic treatment on Vu blocks & in hands on sessions	2	14 August 2010
Treatment Process	6	26 August 2010
Assessment of pre 7 post op radiograph	6	26 August 2010

Membership of the Committee

The members of the Ethics Committee who were present at the meeting are listed on the attached sheet.

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees (July 2001) and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

After ethical review

Now that you have completed the application process please visit the National Research Ethics Service website > After Review

You are invited to give your view of the service that you have received from the National Research

Ethics Service and the application procedure. If you wish to make your views known please use the feedback form available on the website.

The attached document "After ethical review – guidance for researchers" gives detailed guidance on reporting requirements for studies with a favourable opinion, including:

- Notifying substantial amendments
- Adding new sites and investigators
- Progress and safety reports
- Notifying the end of the study

The NRES website also provides guidance on these topics, which is updated in the light of changes in reporting requirements or procedures.

We would also like to inform you that we consult regularly with stakeholders to improve our service. If you would like to join our Reference Group please email referencegroup@nres.npsa.nhs.uk.

10/H0718/69	**Please quote this number on all correspondence**

With the Committee's best wishes for the success of this project

Yours sincerely

PP J Kidd

Dr John Keen
Chair

Email: Julie.kidd@nwlh.nhs.uk

Enclosures: *List of names and professions of members who were present at the meeting and those who submitted written comments*
"After ethical review – guidance for researchers"

Copy to: *Mr Keith Brennan*
The Health Schools
Hodgkin Building
1.8 London Bridge
SE1

Central London REC 1

Attendance at Committee meeting on 29 September 2010

Committee Members:

Name	*Profession*	*Present*	*Notes*
Sir Adrian Baillie	Financial Investment Advisor	Yes	
Dr Sue Birtwistle	General Practitioner	Yes	
Dr Daniel Bradford	Pharmacologist	Yes	
Dr Peter Brodrick	Consultant Anaesthetist	Yes	
Mr Clive Carsley	Retired Lawyer	No	
Mrs Emma Crawford-Collins	Communications Director	Yes	
Dr Parastou Donyai	Senior Lecturer in Pharmacy Practice	Yes	
Dr Olivia Festy	Clinical Trials Administrator	Yes	
Mrs Rosie Glazebrook	Consumer Marketing	Yes	
Dr Leslie Huson	Statistician	Yes	
Dr John Keen	General Practitioner	Yes	
Dr Linda McDonald	Nurse Consultant	Yes	
Dr Amin Rahemtulla	Consultant Haematologist	Yes	
Dr Deborah Rutter	Qualitative Researcher	Yes	
Professor Lewis Spitz	Emeritus Nuffield Professor of Paediatric Surgery	Yes	
Dr Gareth Tudor-Williams	Consultant in Paediatric Infectious Diseases	No	

Also in attendance:

Name	*Position (or reason for attending)*
Ms Julie Kidd	Acting Coordinator

Appendix I: Research and Development approval

King's College Hospital NHS
NHS Foundation Trust

Research & Development
King's College Hospital NHS Foundation Trust
1st Floor, Jennie Lee House
34 Love Walk
London SE5 9RS

Tel: 020 3299 9000
Fax: 020 3299 3445
Minicom: 020 3299 9009
www.kch.nhs.uk

Direct tel: 020 3299 1981
Direct fax: 020 3299 5515

Dr Jennifer Gallagher
Dental Public Health
Kings College London Dental Inst
Denmark Hill
Caldecot Road
London
SE5 9RW

13 January 2011

Dear Dr Gallagher

Title: Quality of Care - DwSI Endodontics in Primary Care

In accordance with the Department of Health's Research Governance Framework for Health and Social Care, all research projects taking place within the Trust must receive a favourable opinion from an ethics committee and approval from the Department of Research and Development (R&D) prior to commencement.

- **Ethics number: 10/H0718/069**
- **Sponsor: King's College London**
- **Funder: No cost to Trust, no funding**
- **End date: 31/03/2012**
- **Protocol: v6**
- **Site: King's College Hospital**
- **R&D approval Date: 13/1/11**

R&D have reviewed the documentation submitted for this project and I am pleased to inform you that we are approving the work to proceed within **Kings College Hospital NHS Foundation Trust** and has been allocated the Trust R&D registration number **KCH11-006**. Please quote the R&D registration number in any communications with the R&D Department regarding your project.

Conditions of NHS Permission for research:

- The Principal Investigator must notify R&D of the actual end date of the project.
- The Principal Investigator is responsible for ensuring that Data Protection procedures are observed throughout the course of the project.
- The project must follow the agreed protocol and be conducted in accordance with all Trust Policies and Procedures especially those relating to research and data management.
- R&D must be notified of any changes to the protocol prior to implementation.
- Please submit a copy of the progress report on the anniversary of the Ethics favourable opinion **(8 October)**

If appropriate it is recommended that you register with the Current Controlled Trials website; http://isrctn.org/

Please ensure that you are aware of your responsibilities in relation to The Data Protection Act 1998, NHS Confidentiality Code of Practice, NHS Caldicott Report and Caldicott Guardians, the Human Tissue Act 2004, Good Clinical Practice, the NHS Research Governance Framework for Health and Social Care, Second Edition April 2005 and any further legislation released during the time of this study.
Members of the research team must have appropriate substantive or honorary contracts with the Trust prior to the study commencing. Any additional researchers who join the study at a later stage must also hold a suitable contract.

If the project is a clinical trial under the European Union Clinical Trials Directive the following must also be complied with:

1. The EU Directive on Clinical Trials (Directive 2001/20/EC) and UK's implementation of the Directive: The Medicines for Human Use (Clinical Trials) Regulations 2004;
2. The EU Directive on Principles and Guidelines for Good Clinical Practice (EU Commission Directive 2005/28/EC); and UK's implementation of the Directive: The Medicines for Human Use (Clinical Trials) Amendment Regulations 2006;

Amendments
Please ensure that you submit a copy of any amendments made to this study to the R&D Department.

Annual Report
It is obligatory that an annual report is submitted by the Chief Investigator to the research ethics committee, and we ask that a copy is sent to the R&D Department. The yearly period commences from the date of receiving a favourable opinion from the ethics committee.

Should you require any further information please do not hesitate to contact us.

In line with the Research Governance Framework, your project may be randomly selected for monitoring for compliance against the standards set out in the Framework. For information, the Trust's process for the monitoring of projects and the associated guidance is available from the Trust's intranet or on request from the R&D Department. You will be notified by the R&D Department if and when your project has been selected as part of the monitoring process. No action is needed until that time.

Many thanks for registering your research project

Yours sincerely,

K Hedditch

Kirsty Hedditch
Research Governance Coordinator

cc. Sponsor: Keith Brennan, Director of Administration (Health Schools), Kings College London Strand, London WC2R 2LS

NHS
Brent

Applied Research Unit
Wembley Centre for Health & Care
116 Chaplin Road
Wembley
Middlesex
HA0 4UZ

Tel: 020 8795 6730/5
Fax: 020 8795 6737

Email: ricky.banarsee@brentpct.nhs.uk

Dr Jennifer E Gallagher
Dental Public Health,
King's College London Dental Institute
Denmark Hill
Caldecot Road,
London
SE5 9RW

24th January 2011

Dear Jennifer

Project Title:	Exploring the relationship between the quality of care provided by general dental practitioners with a special interest in Endodontics and the clinical, radiographic and patient related outcome of endodontic treatment	
REC	10/H0808/116	
Portfolio No	N/A	CSP No N/A

Thank you for your assistance providing the documentation for the scrutiny of the proposal.

I am satisfied that your proposal meets with the requirements of the Research Governance Framework (RGF). The West London Consortium for Research and Innovation is happy to approve your study on behalf of NHS Hammersmith & Fulham and NHS Hounslow on the understanding that you adhere to the RGF conditions on the attached document.

The end date of the project is listed as March 2012.

The documents received and approved were: -

R&D form	
SSIF Hammersmith & Fulham – Ghauri Dental Centre Shepherds Bush W12 0LU and NHS Dentist at 355 North End Road, Fulham SW6 1NW SSIF Hounslow - Heart of Hounslow Health Centre, 92 Bath Road TW3 3EL	
Central London Research Ethics Service favourable ethical opinion letter	08/11/10
All study documents as per REC letter listed above	

Research Governance Requirement

From the information provided and the requirement of the Research Governance Framework have been satisfied in the following areas: -

Check list
The study has received peer review within King's College London Dental Institute and approved for MPhil registration

Use of PCT resources – The DwSI Patients will be sent an information sheet and consent forms along with their appointment. Practice staff will be trained and briefed to answer routine questions about the research. The receptionist will post the envelopes containing the completed questionnaires at the end of each day. The dentists' views on the course will be obtained by way of an online questionnaire.
Data Protection – R&D Form states A37-8 states #All questionnaires and forms containing treatment or outcome data will be anonymised and have unique identifiers. Data will be kept on a password protected database that is kept on a password protected computer and an encrypted USB device. All paper copies (except consent forms) will not contain personal details therefore will be anonymous. The consent forms will be kept separately and securely at Kings College London.' **Please note it is the responsibility of the sponsor to ensure all patient identifiable data stored electronically is encrypted**
Research Passport – the researcher will require a NHS letter of Access issued by NHS Brent before the research starts.

Please ensure that you:
1) Report all SUSARs (Serious unexpected serious adverse reaction) to the Research Ethics Committee and any affecting our patients should be reported to Sylvia Westrup. Failure to abide by this will result in the withdrawal of the Trust's approval.

2) Respond to any requests from Brent PCT's, which hosts the audit function, and provide it with any project amendments, project extensions or terminations. PCTs are required by the Research Governance Framework to maintain a comprehensive database of all research projects.

3) Inform us that the study has been completed by sending a copy of the NRES 'Declaration of the End of Study' form (or completing our brief end of study report form which will be emailed to you after the end date), a summary of the final report and the number of patients/staff from NW London who took part in your study.

Please do not hesitate to contact the RMG Unit (Sylvia Westrup, s.westrup@imperial.ac.uk) if you require further assistance.

With kind regards

Ricky Banarsee
Director WeLReN/Applied Research Unit at Brent PCT
North West London Research Management Governance Unit

CI - jenny.gallagher@kcl.ac.uk
PI - shiyanaeliyas@hotmail.com
Sponsor: keith.brennan@kcl.ac.uk

CONDITIONS RELATING TO RESEARCH GOVERNANCE APPROVAL

1. **Amendments, extensions, discontinuation or temporary suspension of the project**
   No changes or extension can be made to the protocol without prior written approval from the relevant ethics committee. **This includes changing the person who is delegated to carry out the study**. The unit requires a copy of the ethics committee amendment form and approval letter. The unit should also be notified if the project is discontinued or suspended for six months or more.

2. **Honorary Contract and CRB check for non-NHS researchers**
   It is a requirement of the NHS Research Governance Framework that all non-NHS researchers who have contact with patients or service users which has *a direct bearing on the quality of their care,* or access to identifiable patient data, tissues or organs with likely direct bearing on the quality of their care need to obtain honorary contracts with the relevant Trusts **before the study can proceed**. Researchers who have direct contact with patients, service users, children or vulnerable patients also require a CRB check. This should be undertaken by the employing organisation and a copy provided for the PCT in the form of a research passport.

3. **Adverse events**
   Any unusual, unexpected or adverse clinical conditions, particularly if this directly involves patients, should be notified to the unit and ethics committee.

4. **Misconduct and Fraud**
   It is the responsibility of the researchers to notify the unit if they suspect professional misconduct or scientific fraud is taking place during the study. All information will be treated confidentially.

5. **Public participation in research**
   Participants or their representatives should be involved wherever possible in the design, conduct and reporting of research.

6. **Dissemination**
   Whilst it is understood that researchers strive to have their work accepted and published by a peer review journal, it is also important to inform PCTs about any general conclusions that would have an immediate effect on the PCT and ensure that the participants are informed of the general outcome of the study.

7. **Intellectual Property**
   In accordance with the Health and Social Care Act 2001 the Trust has a right to benefit from Intellectual Property arising during the study. If there is potential for IP interest, you should notify the unit.

8. **Funding**
   Research Governance approval by the PCT(s) does not imply that the PCT will provide funding for the project. All projects should be adequately funded and have a recognised sponsor. For 'unfunded' student projects, the funder and sponsor is considered to be the higher education institute where they are registered unless we have received prior notification of an alternative arrangement.

9. Duty of Care

In giving Research Governance approval to the study the Trust(s) accept the responsibilities of normal duty of care to patients and staff who participate in the study.

10. Monitoring

Approval is given on the understanding that the unit will monitor the project and visit a random sample of studies, to ensure they are compliant with the Research Governance Framework requirements.

11. Data Protection

It is essential that information to which the researcher(s) has access regarding both patients and staff should be treated in the strictest of confidence. While working on the research study you will be expected to become familiar with the Trust's confidentiality policies and procedures and agree to abide by them. Failure to observe confidentiality constitutes gross misconduct. This will be liable to disciplinary action. This is in accordance with the Data Protection Act, 1984 and the Health Records Act 1990.
All electronic storage of patient identifiable data must be encrypted as per NHS standards. Guidance can be found at
http://www.connectingforhealth.nhs.uk/systemsandservices/infogov/security/encryption.pdf
The NHS Code of Confidentiality Code of Practice can be found at
http://www.dh.gov.uk/en/Managingyourorganisation/Informationpolicy/PatientConfidentialityAndCaldicottGuardians/DH_4100550

12. GP Practices

Approval is given on the understanding that the unit will be informed of the details of the GP practices involved in the study.

North East London NHS

NHS Foundation Trust

Research and Development Office
North East London NHS Foundation Trust,
1st Floor Maggie Lilley Suite,
Goodmayes Hospital,
Barley Lane,
Goodmayes,
Essex, IG3 8XJ

Date: 03.05.2011

Dear Dr Jennifer Gallagher,

R&D Reference number: **2298**

REC Reference number: **10/H0718/69**

Exploring the relationship between the quality of care provided by general dental practitioners with a special interest in Enodontics and the clinical, radiographic and patient related outcome of endodontic treatment

I am pleased to inform you that the above named study has been granted approval and indemnity by Professor Martin Orrell, Director of Research and Development North East London NHS Foundation Trust. You must act in accordance with the North East London NHS Foundation Trust's policies and procedures, which are available to you upon request, and the Research Governance Framework. Should any untoward events occur, it is **essential** that you contact your Trust supervisor and the Research and Development Office immediately. If patients or staff are involved in an incident, you should also contact the Governance and Assurance department, in Goodmayes Hospital, and complete the Incident and Reporting Form, namely the IR1 form.

You must inform the Research and Development Office if your project is amended and you need to re-submit it to the ethics committee or if your project terminates. This is necessary to ensure that your indemnity cover is valid and also helps the office to maintain up to date records.

You are also required to inform the Research and Development Office of any changes to the research team membership, or any changes in the circumstances of investigators that may have an impact on their suitability to conduct research.

Yours sincerely,

Sandeep Toot

Research and Development Manager, North East London NHS Foundation Trust and Barking and Dagenham Community Health Services

St George's Joint Research Office (JRO)
Ground Floor, Hunter Wing, St George's University of London,
Cranmer Terrace, Tooting, London SW17 0RE

St George's Healthcare NHS
NHS Trust
Community Services Wandsworth

Direct Line: 020 8725 4075
Direct Fax: 020 8725 0794
Email: Maggie.Elliott@stgeorges.nhs.uk

Dr Jenny E Gallagher
Unit of Oral health Research Services & Dental Public Health
2nd Floor, Dental Annex
King's College London Dental Institute
Caldecot Road, London SE5 9RW

31 January 2010

Dear Dr JE Gallagher,

Chief investigator: Dr JE Gallagher
PI: Miss Shiyana Eliyas
Study title: Quality of care- DwSI endodontics in primary care.
R&D Reference: 2010/401 K,W
REC reference: 10/H0718/69

Thank you for providing us with the documentation relating to your research project. St George's Healthcare NHS Trust Community Services Wandsworth is the lead Research Management & Governance office for Croydon, Kingston, Richmond, Sutton & Merton and Wandsworth PCTs and Your Healthcare (Kingston).

NHS permission for the above research has been granted on the basis described in the application form and supporting documentation on behalf of **NHS Kingston and NHS Wandsworth** subject to the conditions listed below and overleaf. Permission is granted on the understanding that the study is conducted in accordance with the Research Governance Framework and NHS Trust policies and procedures. Permission is only granted for the activities for which a favourable opinion has been given by the REC.

All amendments (including changes to the local research team) need to be submitted in accordance with guidance in IRAS. Please also inform us of changes to the status of the project.

If you require any further information, do not hesitate to contact Maggie Elliott (contact details above).

Yours sincerely,

MElliott

Research Governance Coordinator for SW London Primary & Community Care

p.p. Paul Craven, Head of Joint Research Office, St. George's University

c.c.
Miss Shiyana Eliyas- King's College London
Mr Keith Brennan- R&D office at King's College London
Dr Jonathan Hildebrand- NHS Kingston
Nick Kendall- Consultant in Dental Public Health

St George's University of London

St George's Healthcare NHS Trust
Community Services Wandsworth

St George's Research Office
Ground Floor, Hunter Wing, St George's University of London,
Cranmer Terrace, Tooting, London SW17 0RE

The above study is approved subject to the following conditions:

There will be no call upon the NHS organisation's resources other than any mentioned in the application and agreed with the NHS organisation.

The research sponsor or the CI or the local PI at the research site may take appropriate urgent safety measures in order to protect research participants against any immediate hazard to their health or safety. The Research Office should be notified that such measures have been taken. The notification should also include the reasons why the measures were taken and the plan for further action. The R&D office should be notified within the same time frame as the REC and any other regulatory bodies.

The Trust must be notified promptly of any adverse incidents involving patients, staff or anyone else that occur during or as a result of this research.

Your organisation must have in place procedures for detecting and dealing with misconduct and fraud. All researchers must be aware of these procedures and any instances must be reported to us. Alternatively suspected incidents may be reported, in confidence, directly to us.

Unless you request otherwise, we will include details of this project on the Trust and sector databases.

We will ask you to provide a brief progress report on each anniversary of this approval and on completion. Please inform us when the study ends by sending a copy of the NRES Declaration of the end of study form and send us a copy of your final report and/or a summary of your findings.

This project may be randomly audited to ensure the requirements of the Research Governance Framework and other legal and regulatory requirements are being met.

You should notify us if the Trust has claim to any Intellectual Property arising from this study.

Only members of the clinical care team can access patient identifiable information without the patent's consent. Researchers are not part of the clinical care team and therefore require a patient's consent for access to their confidential data.

You must comply with current information governance (IG) requirements. Any IG queries should be discussed with the Trust's IG lead.

Optional
The research must not start until letters of access have been issued and we will write to you separately about this.

St George's Healthcare NHS
NHS Trust
Community Services Wandsworth

St George's University of London

St George's Joint Research Office (JRO)

Ground Floor, Hunter Wing, St George's University of London,
Cranmer Terrace, Tooting, London SW17 0RE

Miss Shiyana Eliyas
Department of Restorative Dentistry
Charles Clifford Dental Hospital,
Wellesley Road S10 2SZ

31 January 2011

Letter of access for study: Quality of care- DwSI endodontics in primary care.
Reda no: 2010/401 K,W
REC no: 10/H0718/69

This letter confirms your right of access to conduct research through **NHS Kingston and NHS Wandsworth** for the purpose and on the terms and conditions set out below. This right of access to: 'the course participants/ dentists' clinical log diaries containing patients' names and addresses to send questionnaires to patients' commences on **31 January 2011 and ends on 31 March 2012** unless terminated earlier in accordance with the clauses below.

You have a right of access to conduct such research as confirmed in writing in the letter of permission for research from this NHS organisation. Please note that you cannot start the research until the Chief Investigator Dr J E Gallagher for the research project has received a letter from us giving permission to conduct the project.

The information supplied about your role in research at NHS Kingston and NHS Wandsworth has been reviewed and you do not require an honorary research contract with this NHS organisation. We are satisfied that such pre-engagement checks as we consider necessary have been carried out.

You are considered to be a legal visitor to NHS Kingston and NHS Wandsworth premises. You are not entitled to any form of payment or access to other benefits provided by this NHS organisation to employees and this letter does not give rise to any other relationship between you and this NHS organisation, in particular that of an employee.

While undertaking research through NHS Kingston and NHS Wandsworth you will remain accountable to King's College London but you are required to follow the reasonable instructions of Mr Nick Kendall in this NHS organisation or those given on his behalf in relation to the terms of this right of access.

Where any third party claim is made, whether or not legal proceedings are issued, arising out of or in connection with your right of access, you are required to co-operate fully with any investigation by this NHS organisation in connection with any such claim and to give all such assistance as may reasonably be required regarding the conduct of any legal proceedings.

You must act in accordance with NHS Kingston and NHS Wandsworth policies and procedures, which are available to you upon request, and the Research Governance Framework.

You are required to co-operate with NHS Kingston and NHS Wandsworth in discharging its duties under the Health and Safety at Work etc Act 1974 and other health and safety legislation. You must observe the same standards of care and propriety in dealing with staff as is expected of any other contract holder and you must act appropriately, responsibly and professionally at all times.

You are required to ensure that all information regarding patients or staff remains secure and *strictly confidential* at all times. You must ensure that you understand and comply with the requirements of the NHS Confidentiality Code of Practice (http://www.dh.gov.uk/assetRoot/04/06/92/54/04069254.pdf) and the Data Protection Act 1998. Furthermore you should be aware that under the Act, unauthorised disclosure of information is an offence and such disclosures may lead to prosecution.

We may terminate your right at any time either by giving seven days' written notice to you or immediately without any notice if you are in breach of any of the terms or conditions described in this letter or if you commit any act that we reasonably consider to amount to serious misconduct or to be disruptive and/or prejudicial to the interests and/or business of this NHS organisation or if you are convicted of any criminal offence.

Your substantive employer is responsible for your conduct during this research project and may in the circumstances described above instigate disciplinary action against you.

NHS Kingston and NHS Wandsworth will not indemnify you against any liability incurred as a result of any breach of confidentiality or breach of the Data Protection Act 1998. Any breach of the Data Protection Act 1998 may result in legal action against you and/or your substantive employer.

If your current role or involvement in research changes, you must inform your employer through their normal procedures. You must also inform Maggie Elliott in this NHS organisation.

Yours sincerely,

MElliott

Research Governance Coordinator for SW London PCTs

cc: **Dr Jennifer E Gallagher- CI King's College London**
Mr Keith Brennan- R&D office at King's College London
Ms Barbara Connolly- HR department, King's College London
Dr Jonathan Hildebrand- R&D Lead NHS Kingston
Nick Kendall- Consultant in Dental Public Health Croydon PCT

research & development centre

rdc

Primary, Community & Social Care

NHS

Southwark
Public Health Department
Hub 2 1st Floor
PO Box 64529
London
SE1P 5LX
Tel: 020 7525 0289
Fax: 020 7525 0318
email: anne.grant@southwarkpct.nhs.uk
www.researchdevelopmentcentre.nhs.uk

Dr Jennifer Gallagher
Oral Health Services Research & Dental Public Health
Dental Public Health
King's College London Dental Institute
Denmark Hill
Caldecot Road
London
SE5 9RW

25/01/2011

Dear Dr Gallagher,

Project Title: Exploring the relationship between the quality of care provided by general dental practitioners with a special interest in Endodontics and the clinical, radiographic and patient related outcome of endodontic treatment
R & D Reference: RDGre573

Thank you for your assistance providing the documentation for the scrutiny of this project.

I am satisfied that this study meets with the requirements of the Research Governance Framework. It has been approved by the research lead for the respective NHS organisation.

Approval is given on behalf of NHS Greenwich on the understanding that you adhere to the conditions on the attached document. The end date of the project is listed as **31/03/2012**.

If you require any further information, please contact Ali Alshukry on 020 7525 0264.

Yours sincerely

Dr Anne Grant
RG & M Manager
South East London NHS
Bexley, Bromley, Greenwich, Lambeth, Lewisham & Southwark

NHS
Newham

R&D Approval Letter

Newham Primary Care Trust
Petra Nittel
Clinical Governance Manager
Governance Department
Unit 10, Warehouse K
2 Western Gateway
London
E16 1DR
Tel: 020 70596747
Fax: 020 70596753
Email: petra.nittel@newhampct.nhs.uk

Miss Shiyana Eliyas
Charles Clifford Dental Hospital
Wellesley Road
Sheffield
S10 2SZ

Date: 22 November 2010

Dear Miss Eliyas

Re: Exploring the relationship between the quality of care provided by general dental practitioners with a special interest in endodontic (root fillings) and the clinical, radiographic and patient related outcome of endodontic (root canal) treatment.

Thank you for providing NHS Newham with information concerning the above study. I am happy to confirm that the Trust has approved the study.

Approval is provided on the basis that you agree to adhere to the Trust's requirements for Research Governance including:

- As Chief Investigator/Principal Investigator for this study you have familiarised yourself with, and accept the responsibilities commensurate with this position, as outlined in the Research Governance Framework (http://www.dh.gov.uk/PolicyAndGuidance/ResearchAndDevelopment/fs/en).
- Compliance with all policies and procedures of the Trust which relate to research, and with all relevant requirements of the Research Governance Framework.
- Co-operating with the Trust R&D Office's regular monitoring and auditing of all approved research projects, including complying with requests for written progress reports.
- Informing the Trust R&D Office *immediately* of any adverse events or complaints, from participants recruited from within this Trust, which occurs in relation to this study.

- Co-operating with the Sponsor organisation in managing, monitoring and reporting of the research study.

- Acknowledge the Trust in any final report and sending a copy of any reports or publications which result from this study to the Trust R&D Office.

Failure to abide by the above requirements may result in the withdrawal of the Trust's approval for this research.

Please contact on 02070596757 or karamjeet.chana@newhampct.nhs.uk or Parveen Inayat 02070596756 parveen.inayat@newhampct.nhs.uk if you need further assistance.

Yours sincerely

Petra Nittel
Clinical Governance Manager

Chair: Marie Gabriel
Chief Executive: Melanie Walker
Professional Executive Committee Interim (PEC) Chair: Dr Ashwin Shah

Appendix J: Ethical Approval extension letter and reply

Dental Institute
at Guys, King's College
and St Thomas'
Hospitals

Denmark Hill Campus
Bessemer Road
London SE5 9RS
Tel +44(0)20 3299 3481
Fax +44(0)20 3299 3409

Oral Health Services
Research & Dental
Public Health

KING'S College LONDON

Dr John Keen
c/o Julie Kidd
National Research Ethics Service
Central London REC 1
Level 7N019, Maternity Block
Northwick Park Hospital
Watford Road

Harrow, Middlesex
HA1 3UJ

05 February 2013

Dear Dr Keen

Minor Amendment

Study: Exploring the relationship between the quality of care provided by general dental practitioners with a special interest in Endodontics and the clinical, radiographic and patient related outcome of endodontic treatment
REC reference number: 10/H0718/69

The Research Ethics Committee kindly reviewed and approved the above named study at the meeting held on 29 September 2010.

This project initially took a lot longer than anticipated to get the relevant permissions to start the data collection etc. and we now find that we are unable to finalise the follow-up questionnaire within the remaining time frame, therefore we would be grateful if you would consider granting us an extension on the end of study for this project to January 2014.

I would be grateful if the committee would take a look at this extension request and approve it.

Thank you for your consideration.

Yours sincerely

Dr J E Gallagher
Senior Lecturer, Honorary
Consultant in Dental Public Health
Head of Department
jenny.gallagher@kcl.ac.uk

www.kcl.ac.uk

cc:

Local Co-ordinators – Nick Kendall
Manny Patel
Jillian Prescott
Claire Roberts
Desmond Wright

Matthew Cole (Barking & Havering)
Research Governance
Barking and Havering PCT
The Clock House
Barking
IG11 8EY
Matthew.cole@bdpct.nhs.uk

Sylvia Westrup (Hounslow)
Hounslow PCT
North West London Research Governance Unit
Room 334, 3rd floor, Reynolds Building
St Dunstan's Road
London. W6 8RP
welren.facil@imperial.ac.uk

Anne Grant (Greenwich & Southwark)
Southwark PCT
Public Health Department
2nd Floor Woodmill, Neckinger
London
SE16 3QN
Anne.grant@southwarkpct.nhs.uk

Maggie Elliott (Wandsworth & Kingston)
NHS Wandsworth,
Community Services Wandsworth
R&D Department, Hartfield Road
Ground Floor, Wimbledon Bridge House
Wimbledon, London
SW19 3RU
Maggie.elliott@wpct.nhs.uk

Jonathan Ray (Hammersmith & Fulham)
Hamersmith & Fulham PCT
5-6 Vencourt Place
Hammersmith
London
W6 9NY
Jonathan.ray@hf-pct.nhs.uk

Amita Shakya (Newham)
Governance Department
Newham PCT
West Beckton Health Centre
2 Monarch Drive
London, E16 3UB
amita.shakya@newhampct.nhs.uk

Health Research Authority
NRES Committee London - Central

Skipton House
80 London Road
London
SE1 6LH

Tel: 020 797 22560

05 February 2013

Dr J E Gallager
Denmark Hill Campus
Bessemer Road
London
SE5 9RS

Dear Dr J E Gallagher

Study title:	**Exploring the relationship between the quality of care provided by general dental practitioners with a special interest in Endodontics and the clinical, radiographic and patient related outcome of endodontic treatment**
REC reference:	**10/H0718/69**
Amendment number:	**Extension of Study**
Amendment date:	**05 February 2013**
IRAS project ID:	**47920**

Thank you for your letter of 05 February 2013, notifying the Committee of the above amendment.

The Committee does not consider this to be a “substantial amendment“ as defined in the Standard Operating Procedures for Research Ethics Committees. The amendment does not therefore require an ethical opinion from the Committee and may be implemented immediately, provided that it does not affect the approval for the research given by the R&D office for the relevant NHS care organisation.

Documents received

The documents received were as follows:

Document	Version	Date
Notification of a Minor Amendment: Letter from Dr J E Gallagher to Dr Keen		05 February 2013

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

10/H0718/69:	**Please quote this number on all correspondence**

Yours sincerely

Kate Donaldson

Kate Donaldson
Assistant Co-ordinator

E-mail: NRESCommittee.London-Central@nhs.net

Copy to: *Mr Keith Brennan*

Appendix K: Information sheet for dentists

NHS London

KING'S College LONDON

DwSI-endodontics **Information sheet for DwSI**

C London REC 10/H0718/69 **26.08.10 Version 6**

Aim of this study

This is a prospective cohort study where the population studied will include the 8 GDPs enrolled in the DwSI in Endodontic Programme (you) and a selection of patients treated by you. It is anticipated that an array of information including patient demographics and referral pattern of the patients treated by you will be gathered during this study, which is aimed at investigating 3 different levels: your perspective of the programme and your own development, the patients experiences and the outcome (clinical and radiographic) of the tooth that is endodontically treated.

How do we measure your skills and care?

Several methods will be used to assess your skills and care.

1. Assessment of clinical and radiographic data regarding the patients treated in practice (from your log book). Please keep a record of all the patients you have treated as part of this teaching programme. Please make sure that you can track the patient using the patient code or patient identifier on the form. Make sure that your log book is up to date.
2. Assessment of Endo-vu blocks completed as part of training
3. In addition, your views will be very useful in improving the DwSI in Endodontics programme. These will be obtained by way of individual interviews (carried out by an individual not involved in teaching or organisation of the DwSI programme) coupled with an online questionnaire.

How do we measure the patient experiences?

This section is likely to include the entire number of patients treated within the 2nd year of the DwSI training programme. These patients will be invited by letter to participate in the study. An information sheet with details of the research project and consent form will be sent (at least 1 week prior to their appointment) to the patient with their appointment. They may contact you to ask questions about this. If you are unable to answer any of the questions please contact Shiyana Eliyas or Jenny Gallagher on the contact details given below. Each patient will be asked about their preferred method of contact (post or e-mail). Any patients who refuse to participate will carry on treatment with the DwSI as normal and a note will be made that he or she declined participation in the study. The refusal to participate in the research study will not affect the treatment he or she will receive. The patient has the right to withdraw from the study at any point. The patient will be asked to complete a written consent form. You and your nurse/receptionists will be trained on how to take consent for this research project.

The patients will be given the questionnaire at the time of presenting to the surgery, prior to the commencement of endodontic treatment. This should take no longer than 15 minutes. The questionnaire will be placed in sealed envelopes and collected by the DwSI at that practice. Follow up questionnaires will be given to the patient at the end of treatment which can be filled at the surgery, placed in a sealed envelope and handed to the DwSI or receptionist at the practice or allowed to be taken away by the patient (if the patient does not complete the questionnaire) and returned at a later date using a stamp addressed envelope. The address on the stamp addressed envelope will be that of the data collection team for this project. A further questionnaire will be sent to patients at 12 months post completion of endodontic treatment.

If patients fail to return the questionnaire, a 1st, 2nd and 3rd reminder will be sent with a copy of the questionnaire on 3 separate occasions. Those that fail to respond will be contacted by telephone and encouraged to give their responses to

Please keep this leaflet for future

the questionnaire over the telephone. The fact that the questionnaire was completed via a telephone conversation with the patient will be clearly noted.

Each of the questionnaires will be tracked using a patient code which will be allocated to each patient at the point of referral. This will allow patient experience to be mapped for the entire care pathway and allow clinical and radiographic outcome to be related to patient reported experience and outcome. The code will include a patient identifier and DwSI participant identifier.

How do we measure the outcome of your endodontic treatment?

The quality of the treatment provided will be inferred from the information gathered regarding the procedure itself. The data will be gathered from the notes and the endodontic treatment summary form filled out by you and kept in your log book. And from the Endo-vu Blocks completed during your training. The quality of the coronal restoration will also be assessed; however it will be borne in mind that this restoration may have been provided by the referring GDP and not you.

Clinical outcome data can be gathered from the logbook notes and radiographs. Technical skill can be assessed using radiographic outcome measures. Data collection will be undertaken by one of the teachers of the DwSI course (SE) and an independent assessor will collect the data.

It is hoped that you will be able to review their patients 12 months post completion of endodontic treatment. This is subject to PCT approval. This will give the opportunity for a review radiograph to assess healing and opportunity for patients to complete the 12 month patient questionnaire. All forms will contain the patient and DwSI participant identifier code. All completed forms will be collected and posted weekly to the data collection team. If PCT approval is not given for this review, patients will receive the follow-up questionnaire by post or e-mail.

What do you have to do?

This is the first time a study of this scale has been carried out. We would be unable to complete it without you. You have at least one week to decide whether or not to assist with the study. We would very much appreciate it if you could help collect as much information as possible. This can be done in the following ways:

1.
2. Ensure that patients attending your service in the last six months receive a copy of the information sheet and consent form along with their appointment at least one week prior to care.
3. Obtain informed consent from patients willing to participate in evaluating this service.
4. Provide participants with a pre-treatment questionnaire.
5. Ensure that all documentation has the confidential patient identifier.
6. Keep good records and keep your log books clear and up to date using the course forms.
7. Provide access to your course log book to inform this evaluation.
8. At the end of care, provide patients with a follow-up questionnaire and business reply envelope
9. Review patients at 12 months if supported to do so by your PCT. Ensure that patients have time to complete the questionnaires.
10. Post all responses back to us using the stamp addressed envelope provided.
11. Permit access to Endo-vu blocks completed during your education and training.
12. Complete a questionnaire at the end of the course about what you thought of this joint service and educational initiative.

Thank you for your help and cooperation. Please do not hesitate to contact us if you have any further questions.

Contact Shiyana Eliyas Telephone: 07738434013 Email: shiyanaeliyas@hotmail.com

Chief Investigator, Dr Jenny Gallagher, Head of OHSR & DPH at KCLDI, Denmark Hill Campus. London SE5 9RW

jenny.gallagher@kcl.ac.uk, Telephone 020 3299 3481

Appendix L: Consent form for dentists

Title of Project: Quality of Care – DwSI Endodontics in Primary Care

DwSI Participant Consent Form

C London REC 10/H0718/69 26.08.10 Version 6

Name of researcher: Shiyana Eliyas, MPhil Student, King's College London Dental Institute

DwSI Identification number for this study

Dentists with a special interest in endodontics: This is a two year programme run by the London Deanery with a view to improving the skills general dental practitioners have in terms of doing root canal treatment in a general practice setting. Data gathered during this evaluation study will provide important information regarding changes in practice following attendance of this course.

I confirm I have read and understood the information sheet for the above training programme ☐

I confirm I have read and understood the information sheet for this research study ☐

I have had the opportunity to consider the information, ask questions and had these answered satisfactorily ☐

I understand that relevant sections of my course log book and training material will form part of the evaluation ☐

I am happy to complete an online questionnaire regarding the DwSI course ☐

My e-mail address is
……………………………………………………………………………………………………

………………………………………	………………	………………………………………
Name of participant	Date	Signature
………………………………………	………………	………………………………………
Name of person taking consent	Date	Signature

Appendix M: Information sheet for the principles or the practices where dentists worked

NHS London

King's College London

DwSI-endodontics

Information sheet for Principals

C London REC 10/H0718/69

26.08.10 Version 6

Aim of this study

This is a prospective cohort study where the population studied will include the 8 General Dental Practitioners (GDPs) enrolled in the (DwSI) in Endodontic Programme and a selection of patients treated by these GDPs. It is anticipated that an array of information will be gathered during this study, which is aimed at investigating 3 different levels: DwSI participant's perspective of the programme, the patient's experiences and the outcome (clinical and radiographic) of the tooth that is endodontically treated.

How do we measure your development throughout the course?

Several methods will be used to assess progress.

1. Assessment of clinical and radiographic data regarding the patients treated in practice (from log book kept by DwSI participant).
2. The views of the DwSI participants will be obtained by way of individual interviews (carried out by an individual not involved in teaching or organisation of the DwSI programme) coupled with an online questionnaire.

How do we measure the patient experiences?

This section is likely to include the entire number of patients treated within the 2nd year of the DwSI training programme. These patients will be invited by letter to participate in the study.

An information sheet with details of the research project and a consent form will be sent to the patient with their first appointment details. They will be asked to complete a written consent form. The DwSI and their nurse will be trained in how to take consent. Each patient will be asked about their preferred method of contact (post or e-mail).

Any patients who refuse to participate will carry on treatment with the DwSI as normal and a note will be made that he or she declined participation in the study. The refusal to participate in the research study will not affect the treatment he or she will receive. The patient can withdraw from the research project at any point.

The patients will be given the questionnaire at the time of presenting to the surgery, prior to the commencement of endodontic treatment. This should take no longer than 15 minutes. The questionnaire will be placed in sealed envelopes and collected by the DwSI participant at that practice or posted by the patient. Follow up questionnaires will be given to the patient at the end of treatment which can be filled at the surgery, placed in a sealed envelope and handed to the DwSI or receptionist at the practice or allowed to be taken away by the patient and returned at a later date using a stamp addressed envelope. The address on the stamp addressed envelope will be that of the data collection team for this project. A further questionnaire will be sent to patients at 12 months post completion of endodontic treatment.

If patients fail to return the questionnaire, a 1st, 2nd and 3rd reminder will be sent with a copy of the questionnaire on 3 separate occasions. Those that fail to respond will be contacted by telephone and encouraged to give their responses to the questionnaire over the telephone. The fact that the questionnaire was completed via a telephone conversation with the patient will be clearly noted.

Each of the questionnaires will be tracked using a patient code which will be allocated to each patient at the point of referral. This will allow patient experience to be mapped for the entire care pathway and allow clinical and radiographic outcome to be related to patient reported experience and outcome. The code will include a patient identifier and DwSI participant identifier.

How do we measure the outcome of your endodontic treatment?

Please keep this leaflet for future

The quality of the treatment provided will be inferred from the information gathered regarding the procedure itself. The data will be gathered from the notes and the endodontic treatment summary form filled out by the DwSI participant and kept in their log book. The quality of the coronal restoration will also be assessed; however it will be borne in mind that this restoration may have been provided by the referring GDP.

Clinical outcome data can be gathered in the same way. This will involve ascertaining improvement in clinical signs and symptoms. Technical skill can be assessed using some of the radiographic outcome measures such as the occurrence of procedural errors, the correction of procedural errors, the presence of voids, the extent and taper of the obturation. To reduce bias, these data collection forms will not be completed by the DwSI participants. One of the teachers of the DwSI course (SE) and an independent assessor will collect the data.

It is hoped that you will be able to review their patients 12 months post completion of endodontic treatment. This is subject to PCT approval. This will give the opportunity for a review radiograph to assess healing and opportunity for patients to complete the 12 month patient questionnaire. All forms will contain the patient and DwSI participant identifier code. All completed forms will be collected and posted weekly to the data collection team.

As well as including patients treated within the duration of the DwSI programme, there may be scope to study previous patients treated by participants in the DwSI programme prior to commencing the programme.

What do you have to do?

This is the first time a study of this scale has been carried out. We would be unable to complete it without you. We would very much appreciate it if you could help collect as much information as possible. This can be done by consenting to allow the DwSI participant from your practice to take part in this research project.

Thank you for your help and cooperation. Please do not hesitate to contact us if you have any further questions.

Contact Shiyana Eliyas Telephone: 07738434013 Email: shiyanaeliyas@hotmail.com

Chief Investigator, Dr Jenny Gallagher, Head of OHSR & DPH at KCLDI, Denmark Hill Campus. London SE5 9RW jenny.gallagher@kcl.ac.uk, Telephone 020 3299 3481

Appendix N: Consent form for principles or the practices where dentists worked

Title of Project: Quality of Care – DwSI Endodontics in Primary Care

Principal Consent Form

C London REC 10/H0718/69 **26.08.10**
Version 6

Name of researcher: Shiyana Eliyas

DwSI Identification number for this study

Dentists with a special interest in endodontics: This is a two year programme run by the London Deanery with a view to improving the skills general dental practitioners have in terms of doing root canal treatment in a general practice setting. Data gathered during this evaluation study will provide important information regarding changes in practice following attendance of this course.

I confirm I have read and understood the information sheet for the above training programme ☐

I confirm I have read and understood the information sheet for this research study ☐

I have had the opportunity to consider the information, ask questions and had these answered satisfactorily ☐

I understand that relevant sections of the log book of the DwSI participant in my practice (which includes radiographs) will form part of the evaluation ☐

I agree for the DwSI participant at my practice and their patients to take part in this research study ☐

....	....	....
Name of participant	Date	Signature
....	....	....
Name of principal	Date	Signature
....	....	....
Name of person taking consent	Date	Signature

Appendix O: Information sheet for patients participating in this study

Title of Project: Quality of Care - DwSI Endodontics in primary care. Information sheet for patients C London REC 10/H0718/69 26.08.10 Version 6

KING'S College LONDON

Introducing Dentists With Special Interests (DwSIs)

This leaflet tells you about dentists with a special interests and what it means if you have been referred to one. It also tells you about the evaluation of this service and how you can let us know what you think about the quality of care.

Who are Dentists with Special Interests?

More of the dental care, which has traditionally been carried out in hospital, can now be offered locally within primary dental care by appropriately trained and experienced practitioners known as 'Dentists with a Special Interest' (DwSIs). In addition to their day-to-day general work, DwSIs can offer patients moderately complex care in a dental practice or clinic. – more than is normally provided by a high street dental practitioner. This means that you will not have to wait for an appointment with a hospital consultant or seek care from a private dentist.

Root canal treatment involves cleaning out and filling the root canal system of a tooth so that a tooth may be saved instead of being removed. A successful outcome is not guaranteed in all cases and loss of the tooth may prove to be inevitable.

The dentist that you will see is an experienced general dental practitioner who is undertaking training to be a DwSI in endodontics. He or she has been building up the knowledge and skills necessary to provide root canal therapy in a level higher than that provided by a general dental practitioner. He or she will assess your needs and will refer you to a specialist or consultant if necessary. After the root canal treatment is finished you will be discharged back to the care of your regular dentist who will retain the responsibility for the completion of treatment. The DwSI will may place a temporary filling as an interim measure. It is your responsibility to look after your teeth and follow homecare instruction given to maximise a successful outcome. If you are eligible for patient charges, standard NHS charges will apply. You will not be charged twice under the same course of treatment.

Please keep this leaflet for future

Quality of the service

The programme has been developed with the help of expert groups. Practitioners with special interests have been used in other parts of the NHS, such as with GPs, nurses and allied health professionals. In these areas, patients are already benefitting from faster and more convenient access to secondary care services, without unnecessary referral to hospital. The London Deanery is responsible for the training content of the course and quality outcomes are central to the vision of the project. The scheme is being run in line with the guidelines for this service issues by the Department of Health (England) and the Faculty of General Dental Practice (UK) to ensure quality and safety for all patients at all times. Practices have been visited to ensure treatment is carried out in a suitable environment and techniques and equipment is modern and up to date.

The NHS, the London Deanery and King's College University have teamed up to evaluate this new service and assess its benefits for patients as well as for NHS itself. The evaluation program will look at the quality of care. Thus, your views as patients and users of this service are very important to us. If you do take part you will be helping to shape future NHS services. We are asking you to complete 3 questionnaires over the forthcoming year and to give us permission to access your anonymised clinical records. We would like to link your responses to a series of three questionnaires to the clinical care provided by the dentists by means of a secure code. This will enable researchers to examine how the care provided is related to the outcome that you experience. All data will be stored securely on a password protected computer and encrypted. It will be securely stored and retained for seven years, after which it will be destroyed.

This study is an evaluation of clinical care that you will be receiving as part of your NHS care. If you are unhappy about any aspect of the treatment you have received then the normal NHS complaints procedures will apply. The Complaints Manager at the practice will be your first point of contact. In case of emergency, please call your own dentist.

What should I do?

There are very few studies which have followed patients for a long time after root canal treatment. You are invited help us assess the service we provide and take part in a long term follow up study (1 year). You will have received this information sheet and consent form in the post with your first appointment. You have at least one week to decide if you want to participate in the evaluation of this service. Please read through these and make a decision prior to your appointment as to whether you would like to take part. If you have any questions please e-mail or phone the Chief Investigator, Dr Jenny Gallagher on the contact details given below. You are not obliged to participate in this evaluation and you are free to withdraw from this research project at any time.

Should you choose to take part, please complete the consent form. You will then be given a questionnaire to complete before your root canal therapy. Please arrive in time to complete the questionnaire beforehand. You will be asked to complete a second questionnaire one week after treatment has been completed and a third questionnaire 12 months after your root canal treatment. Please answer the questions as thoroughly as you can. The answers you provide will be kept confidential. The staff in this practice or in your usual practice will not see your answers. All data will be anonymous. It is your decision as to whether or not you want to take part in this study. A decision not to take part, or to withdraw later, will not affect the service you are about to receive.

What is the purpose of this study?

This evaluation of your treatment and care is being undertaken for educational purposes as part of my MPhil at King's College London.

Shiyana Eliyas, MPhil Student at King's College London Dental Institute

Who has reviewed this study?

This study has been reviewed by the Central London Research Ethics Committee 1 on 29th September 2010. REC reference number: 10/H0718/69.

Need more information?

If you wish to have further information you may speak with the research team at King's College London led by Dr Jenny Gallagher. You can contact them if any part of this leaflet is not clear to you or if you need further information.

Dr Jenny Gallagher, Chief Investigator.

Head of Oral Health Services Research & Dental Public Health, King's College London Dental Institute, Caldicott Road, London SE5 9RW, Telephone 020 3299 3481. E-mail jenny.gallagher@kcl.ac.uk

Appendix P: Consent form for patients participating in this study

Title of Project: Quality of Care – DwSI Endodontics in Primary Care

Patient Consent Form

C London REC 10/H0718/69 **10.12.10 Version 7**

Name of researcher: Shiyana Eliyas, MPhil Student at King's College London Dental Institute

Patient Identification number for this study ☐

Dentists with a special interest in endodontics: This is a two year programme run by the London Deanery with a view to improving the skills general dental practitioners have in terms of doing root canal treatment in a general practice setting. These are fully qualified dentists who are looking to improve their skills. During the course of the programme these dentists will need to carry out root canal treatment on patients. They will keep a log of your treatment and a copy of the x-rays taken. These will be discussed with the tutors of the course and the rest of the group. This information will form part of a research project which will look at changes in practice following attendance of this course. We would also like to invite you to give your thoughts and experiences using 3 questionnaires to be filled in before root treatment, within the 1st month after root treatment and 1 year after the completion of root treatment.

I confirm I have read and understood the information sheet for the above training programme ☐

I confirm I have read and understood the information sheet for this research study ☐

I have had the opportunity to consider the information, ask questions and had these answered satisfactorily ☐

I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my dental care or my legal rights being affected ☐

I understand that relevant sections of my dental notes, and data collected during the study may be looked at by responsible individuals from the research team, from regulatory authorities, from the London Deanery or from the Primary Care Trust, where it is relevant to my taking part in this training programme & research. ☐

I give permission for these individuals to contact me as necessary for follow-up questionnaires for this study ☐

I agree to be treated as part of the above mentioned training programme ☐

I agree to take part in this research study ☐

I am happy to complete the 3 questionnaires ☐

My preferred method of contact is ☐ E-mail address: ....

☐ Postal address: ....

☐ Telephone number: ....

....	....	....
Name of patient	Date	Signature
....	....	....
Name of person taking consent	Date	Signature
Shiyana Eliyas, MPhil Student	....	....
Name of Researcher	Date	Signature

Appendix Q: The intra-examiner agreement and Kappa scores for the cases used for change in skills (Part 1) and maintenance of skills post-training (Part 2)

Intra examiner reliability		**Cases for Part 1 (N= 12 teeth for obturation, N= 11 teeth for complexity)**				**Cases for Part 2 (N= 12 teeth for obturation, N= 10 teeth for complexity and N=3 teeth for healing)**			
		Examiner 1		Examiner 2		Examiner 1		Examiner 2	
		K	%	K	%	K	%	K	%
Obturation	Procedural errors	0.75	92	-0.09	83	0	18	0.63	92
	Working length	1	100	0	25	0.65	82	0	50
	Continuous taper	0.43	83	-0.09	50	0.65	82	0.21	58
	Voids	0.8	92	0.8	92	0.63	82	0.68	83
Complexity	Resorption	0	67	1	100	0.74	90	0	70
	Root curvature	*	100	*	100	0.14	50	0.4	70
	Sclerosis	0.6	80	0.71	88	0	80	*	100
	Position	1	100	1	100	1	100	1	100
	Type of tx	0.81	91	1	100	1	100	1	100
Healing		*	100	*	100	*	100	0	67

* Not able to be calculated due to the lack of significantly different scores

Appendix R: The inter-examiner agreement and Kappa scores for the cases used for change in skills (Part 1) and maintenance of skills post-training (Part 2)

Inter examiner reliability		**First and last 10 cases treated (N=128 cases)**		**Cases treated after completion of course (N=112 cases)**	
		Kappa	%	Kappa	%
Obturation	Procedural errors	0.11	79	0.67	93
	Working length	0.22	70	0.36	73
	Continuous taper	0.28	67	0.46	72
	Voids	0.51	79	0.57	78
Complexity	Resorption	0.55	93	0.06	80
	Root curvature	0.15	90	0.2	83
	Sclerosis	0.51	76	0.64	83
	Position	0.99	99	0.99	99
	Type of tx	0.88	93	0.74	89
Healing				0.35	75

Appendix S: Pre-treatment patient questionnaire

Title of Project: Quality of Care - DwSI Endodontics in primary care

C London REC 10/H0718/69 26.08.10 Version 6

Patient questionnaire (before treatment)

Patient Identification number for this study	

Dear Sir/Madam

You are attending a special root canal treatment service. This is a quite new service to NHS. This form is designed as part of monitoring and evaluation process of this new service. By completing this form, you will help make real improvements to the service. We ensure that every single answer and comment will be reviewed. We intend to ask you to fill in another form at the end of your treatment, so that we can measure if the service has been able to satisfy you. There is space at the end of the form for your comments. All information provided within this form will remain confidential.

<u>NO STAFF IN THIS OR YOUR USUAL DENTAL PRACTICE WILL SEE YOUR RESPONSES OR COMMENTS.</u>

We would like to thank you in advance for helping evaluate this new service. If you wish to have further information you may speak with the research team at King's College London led by Dr Jenny Gallagher. You can contact them if any part of this leaflet is not clear to you or if you need further information.

Dr Jenny Gallagher, Chief Investigator.
Head of Oral Health Services Research & Dental Public Health, King's College London Dental Institute, Caldecot Road, London SE5 9RW, Telephone 020 3299 3481. E-mail jenny.gallagher@kcl.ac.uk

Part A: Getting to the service – questions 1 to 8

1. Have you received a clear explanation of why you were referred to this special root canal treatment service?
   a. Yes ☐ 1
   b. No ☐ 2

2. Which of the following applies to you?
   a. This is my usual dentist who is also providing this special service ☐ 1
   b. My own dentist in this practice referred me to this special service ☐ 2
   c. My own dentist in another practice referred me to this special service ☐ 3

3. If you have been referred, how satisfied are you with being referred to another dentist for part of your treatment?

Very happy	Happy	Unhappy	Very unhappy
☐ 5	☐ 4	☐ 2	☐ 1

4. Do you usually pay for your NHS dental treatment?
   a. Yes ☐ 1
   b. No ☐ 2
   c. Not sure ☐ 3

5. Have you paid your own dentist for this course of NHS care?
   a. Yes ☐ 1 - Go to question 6
   b. No ☐ 2 - Go to question 8
   c. Not sure ☐ 3 - Go to question 8

Part A – continued

6. If you have paid for this course of NHS care, how much did it cost?
   a. Band 1 treatment (= £16.50) ☐ 1
   b. Band 2 treatment (= £45.60) ☐ 2
   c. Band 3 treatment (= £198) ☐ 3
   d. Any other amount ☐ 4
   e. Not sure ☐ 5

7. Was the cost of your treatment clear?
   a. Yes ☐ 1
   b. No ☐ 2
   c. Not sure ☐ 3

If no please suggest how this could be improved:

8. How much would you agree with the following statement?
"I would do anything to save a tooth, no matter how much it costs"

Strongly agree	Agree	Disagree	Strongly disagree
☐ 5	☐ 4	☐ 2	☐ 1

Part B: General questions about your dental health – questions 9 and 10

9. How would you rate your dental health today? Would you say it is:
   a. Excellent ☐ 1
   b. Very good ☐ 2
   c. Good ☐ 3
   d. Fair ☐ 4
   e. Poor ☐ 5

10. Are you suffering from any other problems/conditions (in the mouth) apart from the one for which you are having this specific treatment?
   a. Yes ☐ 1
   b. No ☐ 2
   c. Not sure ☐ 3

If yes what are your problems?

Part C: Continued. Please consider how often you had problems with your mouth or teeth within the **last six (06) months** when answering the following questions.

For each question please tick the box that describes your answer.

	Never	Hardly ever	Occasionally	Fairly often	Very often
19. Have you had to avoid eating some foods because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
20. Has your sleep been interrupted because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
21. Have you been worried by dental problems?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
22. Have you felt depressed because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
23. Have you been a bit embarrassed because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
24. Have you been less tolerant of your partner or family because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
25. Have you felt that your general health has worsened because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
26. Have you been unable to work to your full capacity because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Part C: Detailed questions about the impact of oral health – questions 11 to 26*

This section asks you a series of questions about the impact of your oral health on your life. Please consider how often you had problems with your mouth or teeth within the **last six (06) months** when answering the following questions.

For each question please tick the box that describes your answer.

	Never	Hardly ever	Occasionally	Fairly often	Very often
11. Have you had trouble pronouncing any words because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
12. Have you felt that your sense of taste has worsened because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
13. Have you had food catching in your teeth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
14. Have you had painful aching in your mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
15. Have you had a sore jaw?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
16. Have you had sensitive teeth, for example, due to hot or cold foods or drinks?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
17. Have you had toothache?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
18. Have you been unable to brush your teeth properly because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

* Rasheed's Endodontic Treatment Outcome Index (REOI), adapted from OIHP-49 (Rasheed 2010)

Part C: Continued. Please consider how often you had problems with your mouth or teeth within the **last six (06) months** when answering the following questions.

For each question please tick the box that describes your answer.

	Never	Hardly ever	Occasionally	Fairly often	Very often
19. Have you had to avoid eating some foods because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
20. Has your sleep been interrupted because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
21. Have you been worried by dental problems?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
22. Have you felt depressed because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
23. Have you been a bit embarrassed because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
24. Have you been less tolerant of your partner or family because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
25. Have you felt that your general health has worsened because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
26. Have you been unable to work to your full capacity because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Part D: Finally it would be helpful to have some information about yourself – questions 27 to 30

27. What is your gender?
    a. Male ☐ 1
    b. Female ☐ 2

28. How would you describe your ethnic origin?

WHITE

☐ 1 British
☐ 2 Irish
☐ 3 Any other White background

MIXED

☐ 12 White and Black Caribbean
☐ 13 White and Black African
☐ 14 White and Asian
☐ 7 Any other mixed background

BLACK OR BLACK BRITISH

☐ 4 Caribbean
☐ 5 African
☐ 6 Any other Black background
☐ 7 Any other mixed background

CHINESE OR OTHER ETHNIC GROUPS

☐ 15 Chinese
☐ 16 Any other background

ASIAN OR ASIAN BRITISH

☐ 8 Indian
☐ 9 Pakistani
☐ 10 Bangladeshi
☐ 11 Any other Asian Background

29. Which of the following age bands are you in?
    a. 16 – 24 years ☐ 1
    b. 25 – 34 years ☐ 2
    c. 35 – 44 years ☐ 3
    d. 45 – 54 years ☐ 4
    e. 55 – 64 years ☐ 5
    f. Over 65 years ☐ 6

Part D: Continued.

30. Could you please indicate what your education level is?
    a. Do not have GCSEs or O-levels ☐ 1
    b. GCSEs or O-levels ☐ 2
    c. A-levels ☐ 3
    d. Vocational qualifications ☐ 4
    e. University degree or higher ☐ 5

31. Could you please write down your full Postcode?

--- --- --- --- --- --- ---

Thank you for taking the time to complete this Patient Questionnaire. Please use the space below for any comments or suggestions.

Did you have help with filling in the questionnaire? No ☐ Yes ☐

If yes from who did you receive help?

- From a friend/relative ☐
- From the dentist ☐
- From someone other than the dentist at the practice ☐
- From the interpretation service ☐
- Other (please specify)... ☐

Appendix T: Post-treatment patient questionnaire

Title of Project: Quality of Care - DwSI Endodontics in primary care

C London REC 10/H0718/69 26.08.10 Version 6

Patient questionnaire (immediately after completion of treatment)

Patient Identification number for this study

Dear Sir/Madam

You have recently attended a special root canal treatment service. This is a quite new service to NHS. This form is designed as part of monitoring and evaluation process of this new service. By completing this form, you will help making real improvements to the service. We ensure that every single answer and comment will be reviewed. You might have filled in another form at the beginning of your treatment. We will compare your answers to measure if the service has been able to improve things for you. There's space at the end of the form for your comments. All information provided within this form will remain confidential.

<u>NO STAFF IN THIS OR YOUR USUAL DENTAL PRACTICE WILL SEE YOUR RESPONSES OR COMMENTS.</u>

We would like to thank you for helping evaluate this new service. We would like to thank you in advance for helping evaluate this new service. If you wish to have further information you may speak with the research team at King's College London led by Dr Jenny Gallagher. You can contact them if any part of this leaflet is not clear to you or if you need further information.

Dr Jenny Gallagher, Chief Investigator.

Head of Oral Health Services Research & Dental Public Health, King's College London Dental Institute, Caldecot Road, London SE5 9RW, Telephone 020 3299 3481. E-mail jenny.gallagher@kcl.ac.uk

Part A: About the service – questions 1 to 16

Thinking about your **treatment during the endodontic service**, how do you rate the following:

	Very poor	poor	Good	Very good
1. How thoroughly did the dentist **ask** about your condition?	☐ 1	☐ 2	☐ 4	☐ 5
2. How well did the dentist **listen** to what you had to say?	☐ 1	☐ 2	☐ 4	☐ 5
3. How well did the dentist **explain** your treatment?	☐ 1	☐ 2	☐ 4	☐ 5
4. How well did the dentist explain what you should **expect to feel after the treatment**?	☐ 1	☐ 2	☐ 4	☐ 5
5. How much did the **dentist involve you in decisions**?	☐ 1	☐ 2	☐ 4	☐ 5
6. How well did the dentist **put you at ease** during your treatment?	☐ 1	☐ 2	☐ 4	☐ 5
7. The amount of **time** the dentist spent with you.	☐ 1	☐ 2	☐ 4	☐ 5
8. **Confidence** and **trust** in the dentist.	☐ 1	☐ 2	☐ 4	☐ 5
9. How did you feel about the **cleanliness** within the surgery?	☐ 1	☐ 2	☐ 4	☐ 5

Part A: Continued.

Thinking about the **treatment you received during the endodontic service**, how much do you agree with each of the following statements:

	Strongly disagree	Disagree	Agree	Strongly agree
10. The dentist was **thorough** in doing the procedure.	☐ 1	☐ 2	☐ 4	☐ 5
11. The dentist was **gentle** when they worked on me.	☐ 1	☐ 2	☐ 4	☐ 5
12. I was **satisfied** with what the dentist did.	☐ 1	☐ 2	☐ 4	☐ 5
13. The dentist seemed to **know** what **they were** doing during the procedure.	☐ 1	☐ 2	☐ 4	☐ 5

14. All things considered, how **satisfied** are you with this service?

Very satisfied	Satisfied	dissatisfied	Very dissatisfied
☐ 5	☐ 4	☐ 2	☐ 1

15. Would you consider using this service in future if you needed root canal treatment again?

Definitely yes	Probably yes	Probably not	Definitely not
☐ 5	☐ 4	☐ 2	☐ 1

16. Would you **recommend** this service to your family and friends?

Definitely yes	Probably yes	Probably not	Definitely not
☐ 5	☐ 4	☐ 2	☐ 1

Part B: General questions about your dental health – questions 17 and 18

17. How would you rate your dental health today? Would you say it is:
    a. Excellent ☐ 1
    b. Very good ☐ 2
    c. Good ☐ 3
    d. Fair ☐ 4
    e. Poor ☐ 5

18. Are you suffering from any other problems/conditions (in the mouth) apart from the one for which you are having this specific treatment?
    a. Yes ☐ 1
    b. No ☐ 2
    c. Not sure ☐ 3

If yes what are your problems?

Part C: Detailed questions about the impact of oral health – questions 19 to 34*

This section asks you a series of questions about the impact of your oral health on your life. Please consider how often you had problems with your mouth or teeth **since receiving root canal treatment** when answering the following questions.

For each question please tick the box that describes your answer.

	Never	Hardly ever	Occasionally	Fairly often	Very often
19. Have you had trouble pronouncing any words because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
20. Have you felt that your sense of taste has worsened because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
21. Have you had food catching in your teeth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
22. Have you had painful aching in your mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
23. Have you had a sore jaw?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
24. Have you had sensitive teeth, for example, due to hot or cold foods or drinks?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
25. Have you had toothache?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
26. Have you been unable to brush your teeth properly because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

* Rasheed's Endodontic Treatment Outcome Index (REOI), adapted from OIHP-49 (Rasheed 2010)

Part C: Continued. Please consider how often you had problems with your mouth or teeth **since receiving root canal treatment** when answering the following questions.

For each question please tick the box that describes your answer.

	Never	Hardly ever	Occasionally	Fairly often	Very often
27. Have you had to avoid eating some foods because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
28. Has your sleep been interrupted because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
29. Have you been worried by dental problems?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
30. Have you felt depressed because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
31. Have you been a bit embarrassed because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
32. Have you been less tolerant of your partner or family because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
33. Have you felt that your general health has worsened because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
34. Have you been unable to work to your full capacity because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Section D: Changes in oral health – question 35

This section contains a question about changes in oral health after having a specific treatment.

35. After completion of treatment has your oral health:
    - Improved a lot ☐ 5
    - Improved a little ☐ 4
    - Stayed the same ☐ 3
    - Worsened a little ☐ 2
    - Worsened a lot ☐ 1

36. After completion of treatment has your tooth:
    - Improved a lot ☐ 5
    - Improved a little ☐ 4
    - Stayed the same ☐ 3
    - Worsened a little ☐ 2
    - Worsened a lot ☐ 1

Thank you for your time, effort and co-operation. Please use the space below for any additional information you think can help us to evaluate this service, and for any comment or suggestion.

Did you have help with filling in the questionnaire?
- No ☐
- Yes ☐

If yes from who did you receive help?
- From a friend/relative ☐
- From the dentist ☐
- From someone other than the dentist at the practice ☐
- From the interpretation service ☐
- Other (please specify)... ☐

Appendix U: Follow-up patient questionnaire

Title of Project: Quality of Care - DwSI Endodontics in primary care

C London REC 10/H0718/69 26.08.10 Version 6

Patient questionnaire (at 12 month review)

Patient Identification number for this study

Dear Sir/Madam

You have recently attended a special root canal treatment service. This is a quite new service to NHS. This form is designed as part of monitoring and evaluation process of this new service. By completing this form, you will help making real improvements to the service. We ensure that every single answer and comment will be reviewed. You might have filled in another form at the beginning of your treatment. We will compare your answers to measure if the service has been able to improve things for you. There's space at the end of the form for your comments. All information provided within this form will remain confidential.

NO STAFF IN THIS OR YOUR USUAL DENTAL PRACTICE WILL SEE YOUR RESPONSES OR COMMENTS.

We would like to thank you for helping evaluate this new service. If you wish to have further information you may speak with the research team at King's College London led by Dr Jenny Gallagher. You can contact them if any part of this leaflet is not clear to you or if you need further information.

Dr Jenny Gallagher, Chief Investigator.
Head of Oral Health Services Research & Dental Public Health, King's College London Dental Institute, Caldecot Road, London SE5 9RW, Telephone 020 3299 3481. E-mail jenny.gallagher@kcl.ac.uk

Part A: General questions about your dental health – questions 1, 2 and 3

1. How would you rate your dental health today? Would you say it is:

Excellent	☐ 1
Very good	☐ 2
Good	☐ 3
Fair	☐ 4
Poor	☐ 5

2. Do you still have the tooth that was root canal treated?

Yes	☐ 1
No	☐ 2
Not sure	☐ 3

3. If yes, what sort of filling has been placed?

It still has the temporary filling	☐ 1
A new silver filling	☐ 2
A new tooth coloured filling	☐ 3
A crown / onlay	☐ 4
Not sure	☐ 5

Part B: Detailed questions about the impact of oral health – questions 3 to 19*

This section asks you a series of questions about the impact of your oral health on your life. Please consider how often you had problems with your mouth or teeth within the **last six (06) months** when answering the following questions.

For each question please tick the box that describes your answer.

	Never	Hardly ever	Occasionally	Fairly often	Very often
3. Have you had trouble pronouncing any words because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
4. Have you felt that your sense of taste has worsened because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
5. Have you had food catching in your teeth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
6. Have you had painful aching in your mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
7. Have you had a sore jaw?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
8. Have you had sensitive teeth, for example, due to hot or cold foods or drinks?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
9. Have you had toothache?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
10. Have you been unable to brush your teeth properly because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

* Rasheed's Endodontic Treatment Outcome Index (REOI), adapted from OIHP-49 (Rasheed 2010)

Part C: Continued. Please consider how often you had problems with your mouth or teeth within the **last six (06) months** when answering the following questions.

For each question please tick the box that describes your answer.

	Never	Hardly ever	Occasionally	Fairly often	Very often
11. Have you had to avoid eating some foods because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
12. Has your sleep been interrupted because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
13. Have you been worried by dental problems?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
14. Have you felt depressed because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
15. Have you been a bit embarrassed because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
16. Have you been less tolerant of your partner or family because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
17. Have you felt that your general health has worsened because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
18. Have you been unable to work to your full capacity because of problems with your teeth or mouth?	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Section D: Changes in oral health – question

This section contains a question about changes in oral health after having a specific treatment.

19. After completion of treatment has your oral health:

Improved a lot	☐ 5
Improved a little	☐ 4
Stayed the same	☐ 3
Worsened a little	☐ 2
Worsened a lot	☐ 1

20. After completion of treatment has your oral health:

Improved a lot	☐ 5
Improved a little	☐ 4
Stayed the same	☐ 3
Worsened a little	☐ 2
Worsened a lot	☐ 1

Thank you for your time, effort and co-operation. Please use the space below for any additional information you think can help us to evaluate this service, and for any comment or suggestion.

Did you have help with filling in the questionnaire? No ☐ Yes ☐

If yes from who did you receive help?

From a friend/relative	☐
From the dentist	☐
From someone other than the dentist at the practice	☐
From the interpretation service	☐
Other (please specify)...	☐

Appendix V: Dentists questionnaire regarding their training

DwSI participant questionnaire

1. What previous training or experience have you had in endodontics?

   ....

   ....

2. What did you think of the DwSI in Endodontics Course?

   ....

   ....

3. Did you feel the programme was well organised?

   ....

   ....

4. Which aspects could have been improved?

   ....

   ....

5. Did you feel supported by the course teachers?

   ....

   ....

6. Where could they have helped more?

   ....

   ....

7. Has the training been relevant to general dental practice?

   ....

   ....

8. Do you think you have improved your skills in endodontics?

....

....

9. If so, which areas have improved the most?

....

....

10. What are your views on the NHS arrangements which enabled you to provide a services in primary dental care during the period of training?

....

....

11. How could this have been improvement?

....

....

12. Based on your experience, what do you advice would be helpful commissioning arrangements for DwSIs to provide NHS services in future?

....

....

13. Have you had feedback from the patients regarding their satisfaction and outcomes?

....

....

14. How can the skills you have learned be used within the NHS contract?

....

....

15. What do you think would enhance the ability to provide high quality endodontic treatment in NHS practice?

....

....

Any other comments:

Appendix W: Year 1 data for endodontic training blocks

<table>
<tr><th rowspan="2">Endo training block scores</th><th colspan="3">Procedural errors (Y=0, N=1)</th><th colspan="3">Working length (Y=1 , N=0)</th><th colspan="3">Taper and Shape (Y=1, N=0)</th><th rowspan="2">Endo training block scores</th><th colspan="3">Overall (0=Poor, 3=Good)</th></tr>
<tr><th>Year 0</th><th>Year 1</th><th>Year 2</th><th>Year 0</th><th>Year 1</th><th>Year 2</th><th>Year 0</th><th>Year 1</th><th>Year 2</th><th>Year 0</th><th>Year 1</th><th>Year 2</th></tr>
<tr><td rowspan="2">0</td><td rowspan="2">7</td><td rowspan="2">4</td><td rowspan="2">3</td><td rowspan="2">6</td><td rowspan="2">2</td><td rowspan="2">0</td><td rowspan="2">7</td><td rowspan="2">5</td><td rowspan="2">3</td><td>0</td><td>6</td><td>2</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td rowspan="2">1</td><td rowspan="2">0</td><td rowspan="2">3</td><td rowspan="2">5</td><td rowspan="2">1</td><td rowspan="2">5</td><td rowspan="2">8</td><td rowspan="2">0</td><td rowspan="2">2</td><td rowspan="2">5</td><td>2</td><td>0</td><td>1</td><td>0</td></tr>
<tr><td>3</td><td>0</td><td>2</td><td>5</td></tr>
<tr><td>Missing</td><td>1</td><td>1</td><td>0</td><td>1</td><td>1</td><td>0</td><td>1</td><td>1</td><td>0</td><td>Missing</td><td>1</td><td>1</td><td>0</td></tr>
<tr><td>Total Score</td><td>0</td><td>3</td><td>1</td><td>0</td><td>5</td><td>8</td><td>0</td><td>2</td><td>5</td><td>Total Score</td><td>1</td><td>10</td><td>18</td></tr>
<tr><td>Mean</td><td>0</td><td>0.43</td><td>0.63</td><td>0.14</td><td>0.71</td><td>1</td><td>0</td><td>0.29</td><td>0.63</td><td>Mean</td><td>0.14</td><td>1.43</td><td>2.25</td></tr>
</table>

Appendix X: Differences between the cases treated towards the end of the training course and those treated after completion of the training

		OHIP-EOM Scores			OHIP-EOM Score change			Quality Scores					
		Pre Tx	Post Tx	Follow-up	Pre Tx to follow up	Pre to post Tx	Post Tx to Follow up	Total Tx Process Score	Total Rad Outcome Score	Total Rad Healing Score	Total clinic Healing Score	Total Complexity Score	Process Quality Score
Date of completion of treatment not stated	Mean	33.5	29.5	24	-2.25	-7.33	-1.3	4	1.5	2	4	9.5	5.5
	N	20	10	4	4	3	10	2	2	1	1	2	2
	SD	10.32	8.70	3.559	6.85	8.39	7.18	0	2.12	.	.	0.71	2.12
Treatment completed after completion of the course (Apr 2011 – Aug2013)	Mean	35.08	31.04	26.11	-5.62	-2.36	-3.56	4.4	2.47	1.56	3.32	8.56	6.82
	N	87	73	38	34	31	64	85	90	26	19	80	77
	SD	11.18	10.16	8.465	8.18	8.06	7.94	0.56	1.19	0.70	0.95	1.99	1.34
Treatment completed in Feb-Mar 2011	Mean	34.15	32.09	25.4	-12.8	-6.5	-3.6	4.58	2.27	0.5	4	6.75	7
	N	13	11	5	5	4	10	12	11	2	1	8	9
	SD	8.78	11.61	3.435	9.78	11.82	8.25	0.515	1.19	0.71	.	1.67	1.12
Total	Mean	34.72	31	25.85	-6.14	-3.18	-3.30	4.41	2.42	1.52	3.38	8.42	6.81
	N	120	94	47	43	38	84	99	103	29	21	90	88
	SD	10.74	10.12	7.737	8.49	8.42	7.84	0.55	1.20	0.74	0.92	2.01	1.34

Appendix Y: Correlations

The Relationship between different domains of Process and Outcome

It could be argued that the attention paid to the process of carrying out root canal treatment may be reflected in the quality of the root filling as seen radiographically (as this is what is often measured as routine in clinical practice). In order to assess the possibility of a relationship between the process of carrying out root canal treatment and the quality of the root filling as seen radiographically, the raw data for the scores for the quality of treatment process in comparison to the score for the quality of the root filling as seen radiographically must be first analysed (as shown in Table 1). This allows for the appraisal of the distribution of the raw data. In order to calculate correlations, there must be sufficient distribution of data across all domains, preferably showing an even distribution.

Table 1: Raw data for the domains of process scores for the quality of clinical treatment provided and the quality of the root filling as seen radiographically

			Process: Quality of root filling as seen radiographically											
			Procedural errors		Total	Working Length		Total	Taper		Total	Voids		Total
			0	1		0	1		0	1		0	1	
Process: Quality of the treatment process of providing root canal treatment	Rubber dam used	0	1	0	1	1	0	1	1	0	1	1	0	1
		1	18	83	101	38	62	100	53	47	100	46	54	100
	Total		19	83	102	39	62	101	54	47	101	47	54	101
	Irrigants used	0	0	0	0	0	0	0	0	0	0	0	0	0
		1	10	45	55	24	30	54	33	21	54	18	36	54
		2	9	38	47	15	32	47	21	26	47	29	18	47
	Total		19	83	102	39	62	101	54	47	101	47	54	101
	Apex locator used	0	0	0	0	0	0	0	0	0	0	0	0	0
		1	19	82	101	40	60	100	54	46	100	47	53	100
	Total		19	82	101	40	60	100	54	46	100	47	53	100
	Patency filing	0	0	1	1	0	1	1	1	0	1	0	1	1
		1	17	73	90	34	55	89	47	42	89	46	43	89
	Total		17	74	91	34	56	90	48	42	90	46	44	90

The correlations are shown in Table 2. In this example, there was a statistically significant correlation between rubber dam and procedural errors, however, due to the lack of cases where rubber dam was not used, these correlations must be disregarded. The same should be applied to data regarding the use of apex locators and patency filing; with larger sample sizes and adequate distribution statistical significant correlations may have been seen. A statistically significant correlation between the use of irrigants and presence of voids within the root filling, which implies that when both recommended irrigants are used (Sodium hypochlorite and EDTA) there is more likelihood of the presence of voids within the root filling. Possible explanation for such correlation should be considered at the time of analysis such as in this example, this correlation may be as a result of time spent on the preparation of the canal system being adequate, however the time remaining for obturation of the canal system being inadequate. If correlations are inexplicable, the validity of the statistical methodology must be questioned at the time of analysis.

Table 2: Correlation between the quality of clinical treatment provided (logbook data) and the radiographic quality of the root filling (post-operative radiograph)

		Procedural Errors	Voids
Rubber Dam	Correlation Coefficient	0.208*	0.107
	Sig. (2-tailed)	0.036	0.286
	N	102	101
Irrigants	Correlation Coefficient	-0.012	-0.284**
	Sig. (2-tailed)	0.902	0.004
	N	102	101

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)

There were no statistically significant correlations seen between the clinical quality of the provision of treatment (treatment process) and the domains of healing as seen radiographically or clinically. Due to the lack of cases where rubber dam, apex locators and patency filing were not used (Table 3), the findings in this example demonstrate the importance of care in interpreting such data because with larger sample sizes and adequate distribution statistical significant correlations may have been seen. Raw data for the scores for the quality of the root filling in comparison to the score for healing seen radiographically, score for healing seen clinically, and score for the presence of a satisfactory coronal seal are shown in Table 4.

The correlations between as aspects of the quality of the root filling and the score for healing seen radiographically, healing seen clinically, and the presence of a satisfactory coronal seal are shown in Table 5. Statistically significant correlation between the presence of procedural errors and clinical signs and symptoms were seen. A statistically significant correlation between the presence of voids within the root filling and the presence of a coronal seal was also seen. However, as in the previous example, due to the small number of cases where procedural errors were present, the correlation seen should be disregarded. With a larger sample sizes and adequate distribution statistical significant correlations may not have been seen.

Table 3: Raw data for the domains of process scores for the quality of clinical treatment provided and the healing as seen radiographically and healing as seen clinically

			Outcome: Healing as seen radiographically 0	1	2	Total	Outcome: Healing as seen clinically — Clinical Signs 0	Clinical Signs 1	Total	Negative Sign 0	Negative Sign 1	Total	Symptoms 0	Symptoms 1	Total
Process: Quality of the treatment process of providing root canal treatment	Rubber dam used	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		1	4	6	19	29	1	21	22	1	31	32	2	31	33
	Total		4	6	19	29	1	21	22	1	31	32	2	31	33
	Irrigants used	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		1	3	3	12	18	0	17	17	0	20	20	1	19	20
		2	1	3	7	11	1	4	5	1	11	12	1	12	13
	Total		4	6	19	29	1	21	22	1	31	32	2	31	33
	Apex locator used	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		1	4	6	19	29	1	21	22	1	31	32	2	31	33
	Total		4	6	19	29	1	21	22	1	31	32	2	31	33
	Patency filing	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		1	4	5	19	28	1	21	22	1	30	31	2	30	32
	Total		4	5	19	28	1	21	22	1	30	31	2	30	32

Table 4: Raw data for the domains of process scores for the quality of the root filling and seen radiographically, healing as seen radiographically, healing as seen clinically and presence of a satisfactory coronal seal

			Outcome: Healing seen radiographically				Outcome: Healing as seen clinically									Coronal Seal		
							Clinical Signs		Total	Negative Sign		Total	Symptoms		Total			
			0	1	2	Total	0	1		0	1		0	1		0	1	Total
Process: Quality of root filling as seen radiographically	Procedural errors	0	1	1	3	5	1	3	4	1	6	7	2	5	7	3	3	6
		1	3	5	16	24	0	17	17	0	23	23	0	24	24	9	15	24
	Total		4	6	19	29	1	20	21	1	29	30	2	29	31	12	18	30
	Working length	0	2	2	7	11	1	7	8	1	12	13	2	11	13	4	8	12
		1	2	4	12	18	0	13	13	0	17	17	0	18	18	8	10	18
	Total		4	6	19	29	1	20	21	1	29	30	2	29	31	12	18	30
	Taper	0	2	4	11	17	0	11	11	0	18	18	1	17	18	8	9	17
		1	2	2	8	12	1	9	10	1	11	12	1	12	13	4	9	13
	Total		4	6	19	29	1	20	21	1	29	30	2	29	31	12	18	30
	Voids	0	3	3	8	14	1	10	11	1	15	16	2	14	16	3	12	15
		1	1	3	11	15	0	10	10	0	14	14	0	15	15	9	6	15
	Total		4	6	19	29	1	20	21	1	29	30	2	29	31	12	18	30

Table 5: Correlation between the domains of the root filling as seen radiographically and healing as seen clinically

		Symptoms	Clinical Signs	Coronal Seal
Procedural Errors	Correlation Coefficient	0.486**	0.461*	0.102
	Sig. (2-tailed)	0.006	0.035	0.591
	N	31	21	30
Voids	Correlation Coefficient	0.254	0.213	-0.408*
	Sig. (2-tailed)	0.167	0.353	0.025
	N	31	21	30

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

The different domains that contributed to the quality of the root filling as seen radiographically have the potential to influence each other, for example the presence of procedural errors may influence the ability to establish the correct working length or achieve the ideal taper. Raw data for the influence of theses domains are shown in Table 6. This was confirmed in the correlations seen. There was a statistically significant correlation between procedural error and working length, procedural errors and taper as well as working length and taper (Table 7).

Table 6: Raw data for the various domains of process scores for the quality of the root filling and seen radiographically and their influence on each other

			Process: Domains of quality of root filling as seen radiographically								
			Working length		Total	Taper		Total	Voids		Total
			0	1		0	1		0	1	
Process: Domains of quality of root filling as seen radiographically	Procedural errors	0	17	1	18	17	1	18	11	7	18
		1	23	62	85	38	47	85	38	47	85
	Total		40	63	103	55	48	103	49	54	103
	Working length	0				30	10	40	19	21	40
		1				25	38	63	30	33	63
	Total					55	48	103	49	54	103
	Taper	0							26	29	55
		1							23	25	48
	Total								49	54	103

Table 7: Correlation between the different domains of the quality of the root filling as seen radiographically

		Procedural Errors	Working Length
Procedural Errors (PE)	Correlation Coefficient		0.525**
	Sig. (2-tailed)		0.000
	N		103
Taper	Correlation Coefficient	0.379**	0.345**
	Sig. (2-tailed)	0.000	0.000
	N	103	103

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

In a similar manner the different domains that contributed to the healing as seen clinically, should also have some influence on each other, for example the presence of symptoms may influence the presence of clinical signs of infection. Raw data for the influence of theses domains are shown in Tables 8 to 11. A statistically significant correlation between clinical signs and symptoms, negative signs and symptoms as well as clinical signs and negative signs was seen (Table 12), however due to the size of the sample and the distribution of the scores, these findings should be interpreted with caution, as larger sample sizes and adequate distribution may mean statistical significant correlations are not present.

Table 8: Raw data for the various domains of outcome scores for healing as seen clinically and their influence on each other

			Outcome: Domains of healing as seen clinically					
			Clinical Signs		Total	Negative Sign		Total
			0	1		0	1	
Outcome: Domains of healing as seen clinically	Symptoms	0	1	1	2	1	1	2
		1	0	20	20	0	31	31
	Total		1	21	22	1	32	33
	Clinical Signs	0				1	0	1
		1				0	20	20
	Total					1	20	21

Table 9: Correlation between the different domains of clinical healing

		Symptoms	Clinical Signs
Symptoms	Correlation Coefficient		0.690**
	Sig. (2-tailed)		0.000
	N		22
Other Negative Sign	Correlation Coefficient	0.696**	1.000**
	Sig. (2-tailed)	0.000	0.000
	N	33	21

**Correlation is significant at the 0.01 level (2-tailed).

Table 10: Raw data for healing as seen radiographically and the various domains of outcome scores for healing as seen clinically

			Outcome: Domains of healing as seen clinically								
			Clinical Signs		Total	Negative Sign		Total	Symptoms		Total
			0	1		0	1		0	1	
Outcome: Healing seen radiographically	Healing	0	0	3	3	0	4	4	0	4	4
		1	0	3	3	0	6	6	0	6	6
		2	0	13	13	0	18	18	1	18	19
	Total		0	19	19	0	28	28	1	28	29

Table 11: Raw data for the presence of a satisfactory coronal seal and healing as seen radiographically and the various domains of outcome scores for healing as seen clinically

		Outcome: Healing as seen radiographically				Outcome: Healing as seen clinically								
						Symptoms		Total	Clinical Signs		Total	Negative Sign		Total
		0	1	2	Total	0	1		0	1		0	1	
Presence of a satisfactory coronal seal	0	0	2	9	11	1	13	14	1	9	10	1	12	13
	1	3	4	10	17	1	18	19	0	12	12	0	19	19
Total		3	6	19	28	2	31	33	1	21	22	1	31	32

There were no statistically significant correlations seen between healing as seen clinically and healing as seen radiographically. There were no statistically significant correlations seen between the presence of a satisfactory coronal seal and any of the domains of healing as seen clinical healing or healing as seen radiographically. Again, this could be as a result of the small sample size and lack of diverse distribution of the scores. These examples demonstrate the potential future use of this data, the methodology for analysis and the potential problems associated with such analyses. In the following subsections, the methodology is tested for future use.

Relationship between Process, Outcome & Patient Related Outcomes (OHIP-EOM)

The process of carrying out root canal treatment, the appearance of the root filling as seen radiographically and the presence of a satisfactory coronal seal have been grouped in this study to give an overall score of the quality of the process of root canal treatment. The outcome of root canal treatment has been scored using healing as seen clinically and healing as seen radiographically. Patient related outcomes have been measured using a self-completed, written series of questionnaires (OHIP-EOM) in order to measure the change in score from pre-root canal treatment to follow up. The relationship between these various scores can be correlated as illustrated in the following example. In this example, the score for the presence of a satisfactory coronal seal has been included in the score for healing as seen clinically as this data were collected at the follow up assessment. Ideally the satisfactory coronal seal should be provided as soon as possible following root canal treatment and the quality of the restoration should be part of the score for the quality of the process and not outcome.

Raw data should be assembled as previously described. In this example, raw data are shown in Table 12 for change in OHIP-EOM scores from pre-treatment to follow-up and this could be repeated for various changes such as pre-treatment to post treatment and post-treatment to follow up. In this example the sample size is small and there is insufficient data with broad distribution to reliably accept the result of no statistically significance, however if there were a larger sample of data, Spearman's Rho correlations can be performed to give a table of results as shown in Table 13. The same process could be carried out for the presence of correlations between domains of process, outcome and change in OHIP-EOM scores as well as complexity of cases.

Table 12: Raw data exploring the relationships between Process, Outcome and change in OHIP-EOM scores from pre-treatment to follow up

		Measure of Quality																	
		Process Quality Score							Total	Outcome Score			Total	Total Quality Score					Total
		3	4	5	6	7	8	9		4	5	6		9	10	11	13	14	
Change in OHIP-EOM score from pre-treatment to follow up	-24	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
	-18	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	-15	1	0	1	0	1	0	0	3	0	1	0	1	0	1	0	0	0	1
	-14	0	0	0	0	1	1	1	3	0	1	0	1	0	0	0	1	0	1
	-12	0	0	1	0	0	0	0	1	0	0	1	1	0	0	1	0	0	1
	-11	0	0	1	0	1	0	0	2	0	0	1	1	0	0	0	1	0	1
	-10	0	0	0	0	1	2	0	3	0	1	1	2	0	0	0	1	1	2
	-9	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
	-8	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	-6	0	1	0	0	1	0	0	2	0	0	1	1	0	0	0	1	0	1
	-5	0	0	0	0	1	1	0	2	0	0	0	0	0	0	0	0	0	0
	-4	0	1	0	0	0	0	0	1	0	1	0	1	1	0	0	0	0	1
	-3	0	0	0	0	1	0	0	1	0	0	1	1	0	0	0	1	0	1
	-2	0	0	0	1	1	0	0	2	0	1	0	1	0	0	1	0	0	1
	0	0	0	0	0	1	1	0	2	1	0	0	1	0	0	1	0	0	1
	1	0	0	1	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
	3	0	0	1	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
	14	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
Total		1	2	6	3	12	7	2	33	5	10	11	11	10	11	14	18	15	11

Table 13: Spearman's Rho correlation coefficients for the relationships between Process, Outcome and change in OHIP-EOM scores at various time periods

		Spearman's rho	Process Quality	Total Outcome Score	Total Quality Score
Change in OHIP-EOM scores from one time period to the next	Change from pre-treatment to follow up	Correlation Coefficient	0.094	-0.227	-0.092
		Sig. (2-tailed)	0.604	0.503	0.789
		N	33	11	11
	Change from pre-treatment to post treatment	Correlation Coefficient	-0.091	-0.189	0.016
		Sig. (2-tailed)	0.627	0.537	0.96
		N	31	13	13
	Change from post-treatment to follow up	Correlation Coefficient	-0.022	0.03	-0.128
		Sig. (2-tailed)	0.871	0.931	0.708
		N	57	11	11

* Correlation is significant at the 0.05 level (2-tailed) ** Correlation is significant at the 0.01 level (2-tailed)

It is paramount that any correlations found are explained logically and clinically. For example, When the score for the correct use of irrigants increased, the score for resorption reduced, therefore indicating that clinicians may be more willing to use both NaOCl and EDTA when there is an absence of resorption possibly from fear over extrusion of irrigants beyond the canal apex. In the presence of resorption of the root, it is less likely that the correct working length will be established. With increasing total complexity score the total radiographic outcome score reduced, the more likelihood of procedural errors, the less likelihood of achieving the correct taper of the preparation. As the number of roots increase the likelihood of achieving a good taper in all canals is reduced. In the presence of sclerosis, the total radiographic outcome score reduces, the likelihood of achieving a procedural error free root filling reduced, the likelihood of achieving a good tapered shape of the canal reduces. When the complexity of the type of treatment provided increases, the total radiographic healing score reduces. When there is resorption, the change in OHIP-EOM scores from pre-treatment to review also increases. When sclerosis is present, the post treatment OHIP-EOM questionnaire score is lower. This relationship is possibly explained by data showing that the presence of sclerosis does not mean that the correct working length is not established, however achieving the correct working length leading to reduction in clinical signs and symptoms is not supported by this data.

Statistically significant positive correlations were seen with treatment process factors such as the lack of procedural errors and lack of clinical signs, symptoms, the achievement of the correct working length, better shape/taper. Achieving better shape/taper of the canal appears to also achieve the correct working length more often. These correlations are as clinically expected. When the treatment process score was higher and the correct irrigants were used, there were more voids in the root filling, When the root filling had more voids, there was more chance of a good coronal restoration present in the access cavity at review. These findings are difficult to explain from a clinical standpoint and therefore the statistical methodology must be questioned. It is very likely that these correlations occurred due to the size and distribution of the raw data being used to test the theory.

Relationships Between Complexity of Cases, Process and Outcome

There were statistically significant correlations between the different domains of complexity contributing to the total score of complexity (Table 14). The correlations were positive between number of roots and root curvature, number of roots and sclerosis, position within the mouth and sclerosis. There were negative correlations between the number of roots and root length, resorption and root curvature, resorption and sclerosis, root length and sclerosis. The raw data for the correlations are shown in Table 15.

Table 14: Correlations between domains of complexity contributing to total complexity scores

		Root Curve	Root Length	Canal not visible (Sclerosis)
No of roots	Correlation Coefficient	0.292**	-0.200*	0.257*
	Sig. (2-tailed)	0.004	0.045	0.011
	N	97	101	96
Position	Correlation Coefficient	0.022	-0.111	0.283**
	Sig. (2-tailed)	0.826	0.286	0.005
	N	100	95	99
Resorption	Correlation Coefficient	-0.199*	0.128	-0.211*
	Sig. (2-tailed)	0.048	0.228	0.036
	N	99	91	99
Root Length	Correlation Coefficient	-0.063	1	-0.209*
	Sig. (2-tailed)	0.55	.	0.047
	N	92	101	91

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Table 15: Raw data for complexity correlations

		Root Curve			Root Length			Sclerosis		
		0	1	Total	0	1	Total	0	1	Total
No of roots	1	23	0	23	20	2	22	15	7	22
	2	20	1	21	22	0	22	4	17	21
	3	23	8	31	35	0	35	8	23	31
	4	17	4	21	21	0	21	6	15	21
	5+	0	1	1	1	0	1	0	1	1
	Total	83	14	97	99	2	101	33	63	96
Position	1	9	0	9	8	1	9	6	2	8
	2	37	9	46	41	0	41	17	29	46
	3	6	0	6	4	1	5	4	2	6
	4	33	6	39	40	0	40	7	32	39
	Total	85	15	100	93	2	95	34	65	99
Resorption	0	66	15	81	74	1	75	24	57	81
	1	18	0	18	15	1	16	10	8	18
	Total	84	15	99	89	2	91	34	65	99
Root Length	0	76	14	90				29	60	89
	1	2	0	2				2	0	2
	Total	78	14	92				31	60	91

As the number of roots increase there was more likely to be root curvatures and sclerosis within the canals, but the root length was more likely to be shorter. Where there was resorption, there was less likely to be neither curved roots nor sclerosis within the canal. With increasing root length there was less likelihood of canal sclerosis. With increasing difficulty of the position of the tooth there was more likelihood of sclerosis within the canal. This may be a product of also having more difficulty talking radiographs of teeth in more difficult positions and superimposition of other structures making visualisation of the canal more difficult. The correlation coefficients are not close to 1 and therefore the correlations are weak despite there being a statistical significance. The presence of larger samples may give statistical significance, which should be interpreted with caution.

There were statistically significant correlations between some of the domains of complexity score as well as the total complexity score for the cases treated and a number of domains within treatment process, radiographic outcome, healing and OHIP-EOM as seen in Table 16. There was a positive correlation between change in OHIP-EOM score from pre-treatment to review and resorption. There were negative correlations between irrigants and resorption, total radiographic outcome score and total complexity score, total radiographic outcome score and total complexity score, total radiographic outcome score and sclerosis, procedural errors and total complexity score, procedural errors and sclerosis, working length and resorption, taper and total complexity score, taper and number of roots, taper and sclerosis, total radiographic healing score and type of treatment provided as well as post treatment OHIP-EOM score and sclerosis.

Scores for the radiographic appearance of the filling reduced with increasing complexity of teeth and in the presence of sclerosis. Fewer irrigants were used in the presence of resorption. There were more procedural errors when the complexity was higher and when there was a presence of sclerosis. Achieving the correct working length was less likely in the presence of resorption. Achieving the correct taper or shape of the canal was less likely when the total complexity score was high, there was an increasing number of roots and in the presence of sclerosis. The total radiographic healing score reduced with increasing complexity of the type of treatment provided. In the presence of resorption, the change in OHIP-EOM scores from pre-treatment to post-treatment was higher. In the presence of sclerosis of the canal, the post-treatment OHIP-EOM score was likely to be lower.

Table 16: Correlations between domains of complexity and treatment process, radiographic outcome, healing and OHIP-EOM scores

		Total Complexity Score	Roots	Tx provided	Resorption	Sclerosis
Irrigants	CC#	-0.108	0	0.187	-0.216*	-0.118
	Sig.^	0.31	0.997	0.066	0.032	0.248
	N	90	109	98	98	98
Total Rad Outcome Score	CC#	-0.280**	-0.164	-0.062	-0.189	-0.240*
	Sig.^	0.009	0.102	0.554	0.068	0.02
	N	86	101	93	94	94
PE	CC#	-0.218*	-0.162	0.007	-0.067	-0.215*
	Sig.^	0.044	0.103	0.945	0.519	0.038
	N	86	102	94	94	94
WL	CC#	-0.195	-0.067	0.104	-0.240*	-0.152
	Sig.^	0.072	0.506	0.321	0.02	0.145
	N	86	101	93	94	94
Taper	CC#	-0.265*	-0.274**	-0.129	-0.077	-0.203*
	Sig.^	0.014	0.006	0.217	0.459	0.049
	N	86	101	93	94	94
Total Rad Healing Score	CC#	-0.282	0.137	-0.468*	-0.203	0.072
	Sig.^	0.172	0.477	0.014	0.301	0.716
	N	25	29	27	28	28
Post Treatment Questionnaire	CC#	-0.123	-0.035	-0.136	0.174	-0.230*
	Sig.^	0.316	0.754	0.249	0.141	0.05
	N	68	84	74	73	73
Change from pre Tx to review	CC#	-0.018	-0.16	0.097	0.344*	-0.243
	Sig.^	0.921	0.317	0.567	0.034	0.142
	N	33	41	37	38	38

#Correlation Coefficient
^2-tailed
**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Tables 17 - 22: Raw data for correlations seen in Table 16

Table 17		Total Complexity Score											
		4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**Total**
Irrigants	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	2	3	1	2	12	14	10	3	0	1	0	48
	2	1	6	1	6	10	6	6	3	2	0	1	42
	Total	3	9	2	8	22	20	16	6	2	1	1	90
Total Rad Outcome Score	0	0	0	0	0	2	4	0	0	2	0	0	8
	1	0	1	0	0	2	1	3	3	0	0	0	10
	2	0	3	1	0	3	5	1	2	0	0	0	15
	3	1	4	1	7	9	7	8	0	0	1	0	38
	4	2	1	0	1	6	3	2	0	0	0	0	15
	Total	3	9	2	8	22	20	14	5	2	1	0	86
PE	0	0	1	0	0	3	4	1	2	2	0	0	13
	1	3	8	2	8	19	16	13	3	0	1	0	73
	Total	3	9	2	8	22	20	14	5	2	1	0	86
WL	0	1	3	0	2	5	10	5	3	2	0	0	31
	1	2	6	2	6	17	10	9	2	0	1	0	55
	Total	3	9	2	8	22	20	14	5	2	1	0	86
Taper	0	0	4	1	1	12	13	5	5	2	1	0	44
	1	3	5	1	7	10	7	9	0	0	0	0	42
	Total	3	9	2	8	22	20	14	5	2	1	0	86
Total Rad Healing Score	0	0	1	0	0	0	1	1	0	1	0	0	4
	1	0	1	0	0	0	2	2	1	0	0	0	6
	2	1	0	0	2	5	4	2	1	0	0	0	15
	Total	1	2	0	2	5	7	5	2	1	0	0	25

Table 18		Number of Roots					
		1	2	3	4	5	Total
Irrigants	0	0	0	0	0	0	0
	1	12	13	22	11	1	59
	2	11	11	16	12	0	50
	Total	23	24	38	23	1	109
Total Rad Outcome Score	0	1	2	3	3	0	9
	1	2	3	7	3	0	15
	2	5	4	4	4	0	17
	3	9	11	14	7	1	42
	4	7	3	6	2	0	18
	Total	24	23	34	19	1	101
PE	0	2	3	8	5	0	18
	1	22	20	26	15	1	84
	Total	24	23	34	20	1	102
WL	0	8	9	13	9	0	39

	1	16	14	21	10	1	62
	Total	24	23	34	19	1	101
Taper	0	7	13	18	14	1	53
	1	17	10	16	5	0	48
	Total	24	23	34	19	1	101
Total Rad Healing Score	0	1	2	1	0	4	1
	1	1	2	1	2	6	1
	2	3	5	8	3	19	3
	Total	5	9	10	5	29	5

Table 19		Type of treatment provided					
		1	2	3	4	5	Total
Irrigants	0	0	0	0	0	0	0
	1	7	46	0	0	1	54
	2	5	31	4	2	2	44
	Total	12	77	4	2	3	98
Total Rad Outcome Score	0	2	5	1	0	1	9
	1	1	12	0	0	0	13
	2	2	12	2	0	0	16
	3	4	33	0	1	1	39
	4	3	12	1	0	0	16
	Total	12	74	4	1	2	93
PE	0	3	12	1	0	1	17
	1	9	63	3	1	1	77
	Total	12	75	4	1	2	94
WL	0	6	27	1	0	1	35
	1	6	47	3	1	1	58
	Total	12	74	4	1	2	93
Taper	0	5	40	3	0	2	50
	1	7	34	1	1	0	43
	Total	12	74	4	1	2	93
Total Rad Healing Score	0	0	3	0	0	1	4
	1	0	4	1	1	0	6
	2	3	14	0	0	0	17
	Total	3	21	1	1	1	27

Table 20		Resorption			Sclerosis		
		0	1	Total	0	1	Total
Irrigants	0	0	0	0	0	0	0
	1	40	14	54	16	38	54
	2	40	4	44	18	26	44
	Total	80	18	98	34	64	98

Total Rad Outcome Score	0	7	2	9	0	9	9
	1	8	5	13	3	10	13
	2	13	3	16	5	11	16
	3	32	7	39	18	21	39
	4	16	1	17	7	10	17
	Total	76	18	94	33	61	94
PE	0	12	4	16	2	14	16
	1	64	14	78	31	47	78
	Total	76	18	94	33	61	94
WL	0	24	11	35	9	26	35
	1	52	7	59	24	35	59
	Total	76	18	94	33	61	94
Taper	0	39	11	50	13	37	50
	1	37	7	44	20	24	44
	Total	76	18	94	33	61	94
Total Rad Healing Score	0	2	2	4	1	3	4
	1	5	1	6	2	4	6
	2	15	3	18	4	14	18
	Total	22	6	28	7	21	28

Table 21		Resorption			Sclerosis		
		0	1	Total	0	1	Total
Post Treatment Questionnaire	16	1	0	1	0	1	1
	17	2	0	2	1	1	2
	18	3	0	3	0	3	3
	20	1	0	1	1	0	1
	21	2	0	2	0	2	2
	22	5	0	5	1	4	5
	23	5	0	5	1	4	5
	24	4	0	4	1	3	4
	25	1	0	1	1	0	1
	26	2	1	3	0	3	3
	27	5	2	7	1	6	7
	28	3	1	4	0	4	4
	29	4	0	4	1	3	4
	30	1	0	1	0	1	1
	31	2	1	3	1	2	3
	32	0	1	1	1	0	1
	33	1	0	1	0	1	1
	34	0	1	1	1	0	1
	35	3	0	3	2	1	3
	36	2	0	2	1	1	2
	37	2	1	3	3	0	3
	38	2	0	2	0	2	2
	39	2	0	2	1	1	2
	42	2	0	2	1	1	2
	43	2	0	2	1	1	2
	44	1	0	1	0	1	1
	49	1	1	2	1	1	2
	51	2	0	2	1	1	2

	56	1	0	1	1	0	1
	59	1	0	1	0	1	1
	67	0	1	1	0	1	1
	Total	63	10	73	23	50	73

Table 22		Resorption			Sclerosis		
		0	1	Total	0	1	Total
Change from pre Tx to review	-24	1	0	1	0	1	1
	-15	3	1	4	1	3	4
	-14	3	0	3	0	3	3
	-12	1	0	1	0	1	1
	-11	2	0	2	1	1	2
	-10	3	0	3	1	2	3
	-9	2	0	2	0	2	2
	-8	1	0	1	0	1	1
	-7	1	0	1	0	1	1
	-6	2	0	2	0	2	2
	-5	2	0	2	1	1	2
	-4	1	1	2	0	2	2
	-3	0	1	1	0	1	1
	-2	3	0	3	1	2	3
	-1	1	0	1	1	0	1
	0	2	0	2	1	1	2
	1	1	0	1	0	1	1
	2	0	1	1	1	0	1
	3	0	2	2	1	1	2
	6	1	0	1	0	1	1
	10	1	0	1	1	0	1
	14	0	1	1	0	1	1
	Total	31	7	38	10	28	38

There were significant positive correlations seen between pre-treatment, post-treatment and review questionnaires as shown in Table 23. Raw data revealed small numbers within each score category.

Table 23: Correlation between the OHIP-EOM questionnaires from one time point to another

		Post Treatment Questionnaire	Review Questionnaire
Pre Treatment Questionnaire	Correlation Coefficient	0.584**	0.421**
	Sig. (2-tailed)	0.000	0.005
	N	84	43
Post Treatment Questionnaire	Correlation Coefficient	1.000	0.552**
	Sig. (2-tailed)	.	0.000
	N	94	38

**Correlation is significant at the 0.01 level (2-tailed).

There was a statistically significant correlation seen between clinical quality of treatment (treatment process) and the OHIP-EOM scores at pre-treatment for total treatment process score. There was also a statistically significant correlation between irrigants and the pre-treatment OHIP-EOM score as well as with the review OHIP-EOM score (Table 24). Raw data revealed small numbers within each score category.

Table 24: Correlation of clinical quality of the root filling and OHIP-EOM scores

		Pre Treatment Questionnaire	Review Questionnaire
Irrigants	Correlation Coefficient	-0.259**	0.297*
	Sig. (2-tailed)	0.010	0.048
	N	99	45

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Appendix Z: Publications from this research

Accepted for publication:

Eliyas S., Briggs P.F.A., Gallagher J.E. The views and experience of dentists who gained Enhanced Skills in Endodontics within a novel Pilot Training Programme. *British Dental Journal*

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Development of quality measurement instruments for root canal treatment.

Eliyas S[1,2], Briggs PF[3], Harris IR[4], Newton JT[1], Gallagher JE[1].

⊕ **Author information**

Abstract

AIM: To devise measurement instruments for 'quality' of root canal treatment to assess training and outcome of general dental practitioners working within primary care settings.

METHOD: Scoring systems relating to quality of root canal treatment were developed using expert consensus and published literature. Domains scored included the Treatment Process, Quality of the Obturation, Clinical Healing, Radiographic Healing and Tooth Complexity. Scoring systems were applied to 10 clinical cases treated by each dentist at the beginning and 10 cases treated at the end of their clinical training and 135 cases treated after completion of training. The dentists recorded the treatment process and clinical healing in clinical logs. Two examiners independently scored the radiographs after undertaking calibration and training. Inter- and intra-examiner reliability of scoring radiographic outcomes was tested using Cohen's Kappa statistics.

RESULTS: An instrument was created with four domains to assess quality (two for process and two for outcome of root canal treatment), and a measure of case complexity. Domains of treatment process (n = 240 teeth), outcome (n = 32 teeth) and complexity (n = 215 teeth) were scored using radiographs. The Kappa scores for intra-examiner reliability between 0.22 and 1, whilst inter-examiner reliability ranged between 0.18 and 0.99.

CONCLUSION: Evidence-based scores for assessment of the quality (process and outcome) and complexity (structure) of root canal treatment were devised. They were reliable, provided that clinicians were trained in record keeping and examiners have in depth training and calibration in the use of the instruments.

KEYWORDS: outcome of root canal treatment; quality measures for root canal treatment; quality of root canal treatment

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Poster abstract available at: https://live.blueskybroadcast.com/bsb/client/_new_default.asp?action=SEARCH&Client=404900)

Abstract | Disclosures

Objectives: Attention to quality of care in the United Kingdom and competence of dental practitioners. Quality in the National Health Service has often involved a 'meeting targets' culture and has been measured using the numbers of patients treated and patient related outcomes. Although the patient perspective is important, it is equally important to objectively assess the standard of treatment provided and cross reference this with objective assessment of outcome. The aim is to devise a measure of 'quality' for endodontic treatment performed by dental practitioners working in primary care settings.Methods: A prospective cohort study assessed quality by measuring treatment process, clinical and radiographic outcome, post-treatment healing and patient related outcomes. Scoring systems were developed using expert consensus and published literature. Previously published systems were dichotomised for ease of use. Calibration and training was completed. Inter and intra examiner reliability was tested. A previously developed oral health impact profile for endodontic outcome measures was used to collect patient related outcomes.Results: 135 patients were recruited to the study, treatment process data was available for 113 patients (84%) and radiographs were available for 108 patients (80%). All OHIP questionnaires were returned by 50 patients (37%). Healing data was available for 33 patients (24%). 70% of cases were completed with high standards of clinical treatment. Where all OHIP questions were completed, the mean OHIP score reduced from 33.2 (95% CI 30.31-36.09) before treatment to 26.5 (95% CI 23.81-29.27).Conclusions: The development of scoring systems to measure quality in dentistry is complex, subjective and extensive data collection required for a true estimate of quality in endodontics.

Abstract

Primary Dental Care Research: Measuring 'Quality' in Endodontics

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Primary Dental Care Research: Measuring 'Quality' in Endodontics

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Introduction

Since the acceptance of evidence based dentistry, attention has turned to quality of care in the United Kingdom. Lord Darzi's report[1] forced a higher degree of scrutiny of 'quality' of care and debate about competence of practitioners. Quality in the National Health Service (NHS) has often involved a 'meeting targets' culture and has been measured using the numbers of patients seen and treated, although a change to assessing patient related outcomes in healthcare has now occurred.

In 2009, the London Deanery established a pilot training programme in line with the Department of Health national policy on Dentists with a Special Interest (DwSI) to address access to and quality of endodontic treatment in NHS primary care[2-4]. It aimed to build expertise in the primary care setting and enable dentists who were generalists to develop enhanced skills in endodontics whilst still continuing to work as a generalist for part of their time.

Outcome depends on the perspective of those measuring it. Only histological sections allow definite outcomes of healing to be assessed. Outcomes of endodontic treatment have previously been studied and assessed by clinicians and researchers using radiograph, clinical signs and symptoms[5,6]. Patients are likely to measure outcome in relation to the absence of symptoms[7,8], function and aesthetics[9] and overall quality of life[10]. Insurance companies and dental public health bodies often ascertain the retention or survival of the tooth following endodontic treatment[11-16]

Objectives

To devise a measure of 'quality' for endodontic treatment performed by dental practitioners working in primary care settings.

Method

All dentists in the pilot programme were invited to participate in this prospective cohort study which assessed quality of endodontics performed by measuring treatment process, clinical and radiographic outcome, post-treatment healing and patient related outcomes. Scoring systems were developed using expert consensus and published literature (Table 1). Previously published systems were dichotomised for ease of use. Calibration and training was completed. Inter and intra examiner reliability was tested. A previously developed oral health impact profile for endodontic outcome measures was used to collect patient related outcomes.

Results

Six of the eight dentists with a special interest recruited 135 patients for this study. Table 2 shows the demographics of the dentists, Table 3 shows the demographics of the recruited patients.

Table 2: Demographics of dentists

Gender	Age	Work setting	Years since qualification	Post graduate teaching in Endo
M = 3 (50%) F = 3 (50%)	Mean 37 yrs SD = 9.34 yrs Range 27-51 yrs Median 36 yrs	GDP = 5 (83.3%) CDS = 1 (16.7%)	Mean 13 yrs SD = 9.38 yrs Range 4 - 27 yrs Median 10 yrs	Yes = 1 (16.7%) No = 5 (83.3%)

Table 3: Demographics of patients recruited

Gender	Ethnic group	Level of education
M = 48 (35.6%) F = 78 (57.8%) Not stated = 9 (6.6%)	White = 94 (69.6%) Black or Black British = 18 (13.3%) Asian or Asian British = 4 (3%) Mixed = 8 (5.9%) Chinese or other = 3 (2.2%) Not stated = 8 (6%)	Do not have GCSEs or O-Levels = 1 (0.7%) GCSE or O-Levels = 30 (22.2%) A levels = 14 (10.4%) Vocational qualifications = 15 (11.1%) University degree or higher = 61 (45.2%) Not stated = 14 (10.4%)

Treatment process data were available for 113 patients (83.7%) and post-operative radiographs were available for 108 patients (80%). Review data were available for 33 patients (24.4%) at 12 months post treatment. Questionnaires for all three time periods were returned by 50 patients (37%), however they were fully completed by only 35 patients (26%).

The use of rubber dam and apex locators during endodontic treatment was reported in 111 patients (82.2%). Patency filing was reportedly carried out in 99 patients (73.3%). Both NaOCl and EDTA were used as irrigants in 52 patients (38.5%). The overall scores for treatment process are shown in Figure 1 and were of a satisfactory standard in 71.1%.

No procedural errors were seen in 72 patients (53.3%). Correct working length was seen in 51 patients (37.8%). Good taper and shape was seen in 41 patients (30.4%) and the root filling was well compacted with no voids in 44 patients (32.6%). The overall scores for radiographic quality are shown in Figure 2. Healing scores were available for 28 patients (20.7%), 13.3% of whom healed, 4.4% remained the same and 3% failed to heal. The inter examiner reliability for scoring radiographs are shown in Table 4.

In general the mean values of the OHIP-EOM reduced from each time period to the next (Table 5). For those who fully completed all questionnaires at all time periods the change in scores are shown in Figure 3.

Table 4: Reliability of scoring system for radiographs

Quality of radiographic treatment and healing	After training		After further calibration		Cases for study	
	Kappa	% Agreement	Kappa	% Agreement	Kappa	% Agreement
Procedural errors	0.48	80%	0.62	87%	0.67	93%
Working length	0.35	65%	0.43	70%	0.36	73%
Continuous taper	0.34	70%	0.73	87%	0.46	72%
Voids	0.43	73%	0.41	80%	0.57	78%
Healing	0.19	72%	0.83	90%	0.35	75%

Discussion

In other studies scoring radiographs for the quality of root filling, complete independent agreement between all examiners occurred in 32% of cases. All observers independently arrived at the same periapical diagnosis in 39% of cases. The opinions of all examiners only coincided in 15% (n=6) of cases[29]. In this study, the agreement between examiners for radiographic scoring ranged from 72% to 93%.

Table 1: Face validity of the scoring system for quality of root canal treatment

Scoring System in this study		Gold standard	Supporting Literature
Treatment process	Rubber Dam used Y=1, N=0	Rubber dam is used	European Society of Endodontics Guidelines, 2006[17]
	Irrigants NaOCl + EDTA = 2 NaOCl=1 Anything else=0	NaOCl with penultimate wash with EDTA and final wash with NaOCl	Ng et al 2011[18] – 0.2% CHX reduces odds of success by 53%. EDTA has no effect on primary RCT but increases odds of success in secondary RCT by 2x
	AL used Y=1, N=0	Use apex locator to determine apical terminus	European Society of Endodontics Guidelines, 2006[17] Real et al 2011[19] - accuracy of finding apical terminus with apex locators 92% vs digital radiographs 65% Silveira et al 2011[20] – accuracy of finding apical terminus with apex locators 82-92%
	Patency filing Y=1, N=0	Gain and maintain patency during treatment	Ng et al 2011[18] – if patency gained 2x as likely to have success
Quality of obturation	Procedural errors Y=0, N=1	No procedural errors	Ng et al 2011[18] – pre-operative root perforation reduces odds of success by 56% Marquis 2006[21] – healing better if no intra-operative complications (OR=2) de Chevigny et al 2008a[22] – mid treatment complications reduce rate of healing by 15% in primary RCT de Chevigny et al 2008b[23] – pre-operative perforation reduces outcome Farzaneh et al 2004[24] – pre-operative perforation reduces outcome by OR of 27 in secondary RCT
	Within 2mm of rad apex Y=1, N=0	Obturation must be in the canal within 2mm of the radiographic apex	Farzaneh et al 2004[24] – root filling 0-2mm from radiographic apex is better than long root filling especially if pre-operative apical area present European Society of Endodontics Guidelines, 2006 Ng et al 2008a[25] – For primary RCT: root filling length affects outcome especially if an apical area already exists. Flush root filling > short root filling > long root filling, if no apical area. Lowest success rate if apical area + short or long Ng et al 2008b[26] – For secondary RCT: short root filling > flush root filling > long root filling (worse if apical area also present Ng et al 2011[18] – Odds of success reduced by 12% for every 1 mm short of the radiographic apex. Odds of success reduced by 62% if the root filling was long
	Continuous taper and shape Y=1, N=0		European Society of Endodontics Guidelines, 2006[17] Schilder 1974[27]
	Voids Y=0, N=1	No voids in the obturation	European Society of Endodontics Guidelines, 2006[17]
Healing	Reduced or no development of an apical area = 2 No change in size of existing apical area = 1 Increased or development of an apical area = 0	Reduction or no development of an apical area	European Society of Endodontics Guidelines, 2006[17] Orstavik 1986[28]

Figure 1: Overall score for clinical quality (treatment process) of treatment

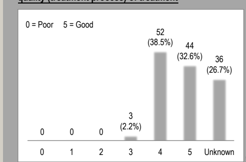


Figure 2: Overall score for quality of root filling (radiographic quality) of treatment

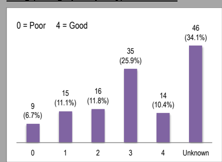
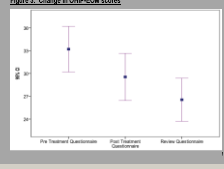


Table 5: Change in OHIP-EOM score from one time period to another:

	Change from preTx to post	Change from preTx to review	Change from postTx to review
N	84	43	38
%	62	32	28
Total score change	-277.0	-264.0	-121.0
Mean	-3.30	-6.14	-3.18
SD	7.835	8.487	8.421
95% CI lower limit	-4.98	-8.68	-5.86
95% CI upper limit	-1.62	-3.6	-0.5
Median	-2	-6	-2
Range	+13 to -28	+14 to -26	+22 to -21

Figure 3: Change in OHIP-EOM scores



This pilot study shows the difficulties that exist in collecting data related to quality of dentistry in primary care (especially in a transient population in a city such as London) and also measuring or quantifying quality. Larger studies are needed to draw reliable conclusions relating quality of care with patient related outcomes

Table 6: Scoring the quality of radiographic outcome and healing

Quality of radiograph	Procedural errors* (Y=0, N=1)	Within 2mm of rad apex inside the root canal (Y=1, N=0)	Continuous taper and shape^ (Y=1, N=0)	Voids (Y=0, N=1)	Total (0=poor, 4=good)	12 month Healing - Apical area (Reduced or no development of an apical area =2 No change in size of existing apical area =1 Increased or development of an apical area =0)

Conclusions

A measure of the quality of the performance of endodontic treatment has been devised. It can be rated consistently both within and between observers. Future studies should adopt this measure as a basis for exploring the relationship between quality of the clinical treatment process, radiographic outcome of the obturation, healing and the patient's perspective.

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